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Roofing, Stair Building, and Sheet-Metal Work

371 Illustrations

By
EDITORIAL STAFF
INTERNATIONAL CORRESPONDENCE SCHOOLS

GEOMETRY AND MENSURATION
STAIR BUILDING
ROOFING
SHEET-METAL WORK

Published by
INTERNATIONAL TEXTBOOK COMPANY
SCRANTON, PA.
1925

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PREFACE

The volumes of the International Library of Technology are made up of Instruction Papers, or Sections, comprising the various courses of instruction for students of the International Correspondence Schools. The original manuscripts are prepared by persons thoroughly qualified both technically and by experience to write with authority, and in many cases they are regularly employed elsewhere in practical work as experts. The manuscripts are then carefully edited to make them suitable for correspondence instruction. The Instruction Papers are written clearly and in the simplest language possible, so as to make them readily understood by all students. Necessary technical expressions are clearly explained when introduced.

The great majority of our students wish to prepare themselves for advancement in their vocations or to qualify for more congenial occupations. Usually they are employed and able to devote only a few hours a day to study. Therefore every effort must be made to give them practical and accurate information in clear and concise form and to make this information include all of the essentials but none of the nonessentials. To make the text clear, illustrations are used freely. These illustrations are especially made by our own Illustrating Department in order to adapt them fully to the requirements of the text.

In the table of contents that immediately follows are given the titles of the Sections included in this volume, and under each title are listed the main topics discussed.

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GEOMETRY AND MENSURATION

(PART 1)

LINES AND PLANE SURFACES

LINES AND ANGLES

DEFINITIONS

1. A **point** indicates position only; it has neither length, breadth, nor thickness.

2. A **line** has only one dimension—length.

3. A **straight line,** Fig. 1, is one that does not change its direction throughout its whole length. A straight line is also frequently called a **right line.**

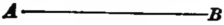

FIG. 1

4. A **curved line,** Fig. 2, changes its direction at every point.

FIG. 2

5. A **broken line,** Fig. 3, is one made up wholly of straight lines lying in different directions.

FIG. 3

Unless otherwise specified, the word *line* is understood to mean a *straight line.*

6. A **surface** has the shape of a body but is without thickness. A surface has but two dimensions—length and breadth.

7. A **flat surface, plane surface,** or simply a **plane,** is a surface such that a straight line between any two of its

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points lies wholly in the surface. If a straightedge is laid on a plane surface in any direction, every point of the straightedge will touch the surface.

8. A **figure** is any combination of points and lines. A figure that lies entirely in one plane is a **plane figure.** In referring to a figure, a point is designated by a letter placed conveniently near it; thus, in Fig. 1, the left end of the line is referred to as "the point *A*." The entire line is referred to as "the line *A B*," the letters *A* and *B* designating two points, usually the ends of the line. If a line is broken or curved, as many points are named as are considered necessary to designate the line.

9. **Geometry** is that branch of mathematics which treats of the properties of lines, angles, surfaces, and volumes.

10. **Mensuration** is that part of geometry which treats of the measurement of lines, surfaces, and volumes.

ANGLES

11. An **angle,** Fig. 4, is the opening between two straight lines that meet in a point. The two straight lines are the *sides*, and the point where the lines meet is the **vertex** of the angle. Thus, in Fig. 4, the straight lines *O A* and *O B* form an angle at the point *O*; the lines *O A* and *O B* are the sides of this angle, and the point *O* is its vertex.

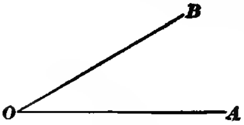


FIG. 4

12. An angle is usually referred to by naming a letter on each of its sides and a third letter at the vertex, the letter at the vertex being placed between the other two. Thus, the angle in Fig. 4 is called angle *A O B* or angle *B O A*.

An angle may also be designated by a letter placed between its sides near the vertex. Thus, the two angles *X C Y* and *Y C Z*, Fig. 5, may be referred to as the angles *A* and *B*, respectively.

An angle that stands alone, that is, an angle whose vertex is not the vertex of any other angle, may be designated by naming the letter at its vertex. For example, the angle in Fig. 4 may be called the angle *O*.

13. Two angles, as *A* and *B*, Fig. 5, having the same vertex and a common side *C Y*, are called **adjacent angles.**

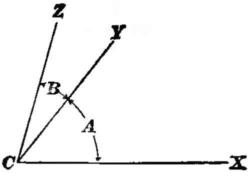


FIG. 5

14. Any angle may be thought of as being formed, or generated, by a line turning about the vertex as a pivot, from the position of one side to the position of the other. Thus, the angle *A O B*, Fig. 4, may be conceived as generated by a line turning about *O* from the position *O A* to the position *O B*. The size of the angle does not depend on the length of the sides, which are supposed to be of indefinite length, but on the opening between the sides; or, what is the same thing, on the amount of turning necessary to bring one side to the position of the other.

15. If a straight line, as *A B*, Fig. 6, meets another straight line, as *C D*, so as to make with it two equal adjacent angles, each of these angles is a **right angle,** and the first line is said to be *normal*, or *perpendicular*, to the second. The point where the first line meets the second is called the *foot* of the perpendicular. It is evident that all right angles are equal.

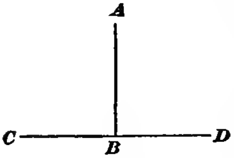


FIG. 6

The edges of the tongue of a carpenter's square, shown in Fig. 7, are perpendicular to those of the body, or long blade, and the angles thus formed are right angles. Thus, *A B* is perpendicular to *B C*, and the angle at *B* is a right angle; *D E* is perpendicular to *E F*, and the angle at *E* is a right angle.

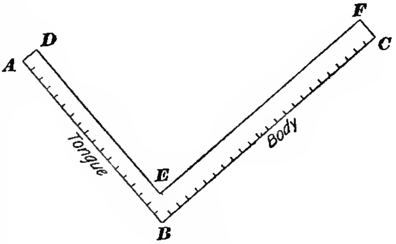


FIG. 7

MEASUREMENT OF ARCS AND ANGLES

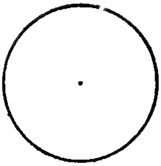


FIG. 8

16. A **circle,** Fig. 8, is a plane figure bounded by a curved line, called the **circumference,** every point of which is equally distant from a point within, called the **center.**

17. The **diameter** of a circle is a straight line passing through the center and terminated at both ends by the circumference, as *A B*, Fig. 9.

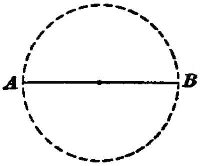


FIG. 9

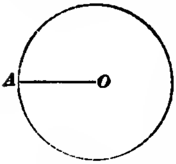


FIG. 10

18. The **radius** of a circle, *O A*, Fig. 10, is a straight line drawn from the center to the circumference. It is equal in length to one-half the diameter. The plural of the word radius is *radii.* All radii of any circle are equal in length.

19. An **arc** of a circle is any part of its circumference, as *A E B*, Fig. 11.

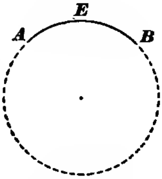
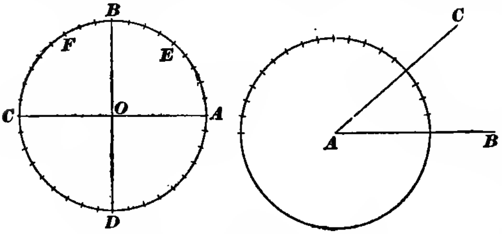


FIG. 11

The whole circumference of every circle is considered as being divided into 360 equal parts, and each of these equal parts is called a **degree**; a degree is divided into 60 equal parts called **minutes**; and a minute is divided into 60 equal parts called **seconds.** Degrees, minutes, and seconds are used as units for measuring circular arcs.



(*a*) FIG. 12 (*b*)

In Fig. 12 (*a*) the circumference is divided into 36 equal parts; hence, each arc between two adjacent division lines contains 360÷36 = 10 degrees. The arc *A E B* is one-quarter of a circumference. A quarter of a circumference is called a **quadrant**; its arc contains $360 \div 4 = 90$ degrees. The arc *E B F* extends over seven divisions; hence, the arc contains $7 \times 10 = 70$ degrees.

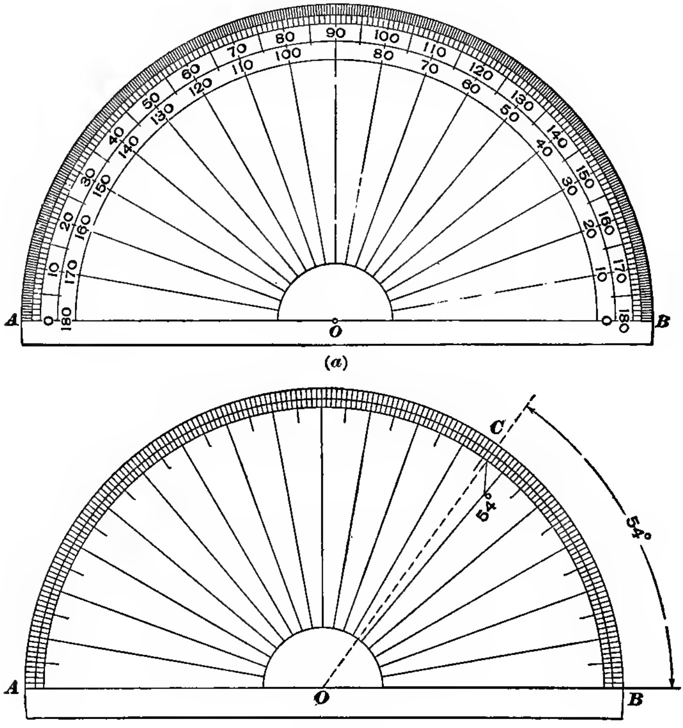
20. Angles, as well as arcs, are measured in degrees, minutes, and seconds. If the vertex of an angle is placed at the center of a circle, the number of degrees in the arc included between the sides of the angle is the number of degrees in the angle. For example, Fig. 12 (*b*) shows a circle of the same size as in (*a*), with half of its circumference divided into short arcs of the same size as in (*a*); that is, each arc between adjacent points of division contains 10 degrees.

Suppose, as indicated in (*b*), that the angle *C A B* is placed with its vertex *A* at the center of the circle. Its sides then include four of the equal small arcs. As each small arc contains 10 degrees, the total arc between *A B* and *A C* contains $4 \times 10 = 40$ degrees; then, the angle *C A B* is said to be an angle of 40°.

In (*a*), the arc *A E B* contains 90 degrees; therefore the angle *A O B* is an angle of 90°. Similarly, the arc *B F C* contains 90 degrees, and so the angle *B O C* is an angle of 90°. This means that the straight line *B O* meets the straight line *C A* in such a way as to form two equal adjacent angles *A O B* and *B O C*; and so, according to Art. **15**, each of these angles is a right angle. In other words, every right angle is an angle of 90°.

21. Angles are commonly measured by the use of a *protractor*, a form of which is shown in Fig. 13 (*a*). It consists of a piece of celluloid or of metal of a semicircular shape and very thin. Along the curved edge are a number of divisions, the smallest representing $\frac{1}{2}°$, or 30′, the next larger representing 1°, and the larger ones representing 5° and 10°, respectively. To use the protractor, it is laid flat on the angle to be measured, with the point *O* directly on the vertex of the angle and the line *A B* directly over one side of the angle. The point where the other side of the angle crosses the scale shows the size of the angle.

22. If a line is given and it is required to draw another line that inclines toward it at a given angle, the required line may be drawn in the following manner: Let *A B*, Fig. 13 (*b*), be the given line and *O* the point from which a line is to be drawn at an angle of 54° with the line *A B*. The protractor, as shown in (*a*), is laid on the line *A B*, as shown in (*b*), so that its center *O* comes directly over the vertex *O* of the angle and so that the line *A B* coincides with the line *A B*. Then 54° is counted off from the lower end *B* of the scale on the protractor. This means 5 large divisions, each of which represents 10°, and 4 small divisions, each of which represents 1°. Opposite the end of the 54° mark the point *C* is located



(*a*)

(*b*)

Fig. 13

with a sharp pencil or a *scriber*, a pointed steel tool used for *scribing*, or scratching, lines on metal surfaces. Then the protractor is removed and a straight line is drawn or scribed so as to pass through C and O. This line $C O$ will make an angle of 54° with the line $A B$; that is, the angle $C O B$ will be 54°.

23. An **oblique angle** is any angle that is not a right angle. An **acute angle** is an oblique angle that is less than a right angle. An **obtuse angle** is an oblique angle that is greater than a right angle. In Fig. 14, $B O C$ and $A O C$ are oblique angles, $B O C$ being an acute angle, and $A O C$ an obtuse angle.

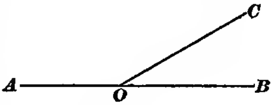


FIG. 14

In carpentry, an angle other than a right angle is known as a *bevel angle*, or *bevel;* hence, any acute angle or any obtuse angle is a bevel angle. The instrument used by the carpenter to lay off acute and obtuse angles is called a *bevel.*

24. Two angles are said to be **complementary** when their sum is equal to one right angle, or 90°. Each of two complementary angles is called the **complement** of the other. Thus, in Fig. 15, in which $A B$ is perpendicular to $B D$, the angles M and N are complementary, their sum being equal to the right angle $A B D$. The angle M is the complement of the angle N; also, the angle N is the complement of the angle M.

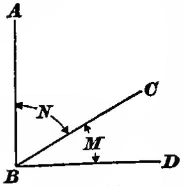


FIG. 15

EXAMPLE.—If the angle $C B D$, Fig. 15, is 31°, what is the complementary angle $A B C$?

SOLUTION.—Since $A B D$ is a right angle, the angle $A B C$ is

$$90° - \text{angle } C B D = 90° - 31° = 59°. \quad \text{Ans.}$$

25. Two angles are said to be **supplementary** when their sum is equal to two right angles, or 180°. Each of two supplementary angles is called the **supplement** of the other. In Fig. 16, $A O D$ and $D O B$ are supplementary angles, their sum being evidently equal to the sum of the two right angles $P O B$ and

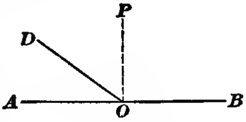


FIG. 16

$P\,O\,A$. Thus, $A\,O\,D$ is the supplement of $D\,O\,B$, and $D\,O\,B$ is the supplement of $A\,O\,D$.

EXAMPLE.—In Fig. 16, the angle $A\,O\,D$ is 45°. What is the supplementary angle $D\,O\,B$?

SOLUTION.—Since angle $A\,O\,D$+angle $D\,O\,B=180°$, angle $D\,O\,B=180°-$angle $A\,O\,D=180°-45°=135°$. Ans.

26. The sum of all the angles formed on the same side of a straight line about the same point in the line is equal to two right angles, or 180°. Thus, in Fig. 17, $M+N+P+Q+R=180°$.

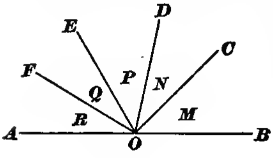


FIG. 17

EXAMPLE.—In Fig. 17, assuming that $R=30°$, $Q=25°$, $P=40°$, and $N=28°$, find M.

SOLUTION.—Since $R+Q+P+N+M=180°$, $M=180°-(R+Q+P+N)=180°-(30+25°+40°+28°)=180°-123°=57°$. Ans.

27. The sum of all the angles formed in the same plane about one point is equal to four right angles. Thus, in Fig. 18,

$$M+N+P+Q+R+S+T+U$$
$$=\text{four right angles}=360°.$$

EXAMPLE.—If the angles N, M, U, etc., Fig. 18, are equal to one another, what is the size of each angle?

SOLUTION.—There are eight equal angles and their sum equals 360°. Hence, each angle is

$$360°\div 8=45°. \quad \text{Ans.}$$

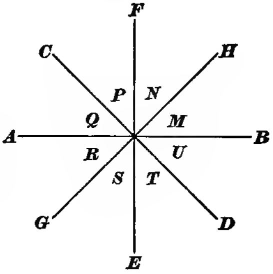


FIG. 18

28. When two lines, as $A\,B$ and $C\,D$, Fig. 19, cut or cross each other, they are said to **intersect**. Their common point O is called their **point of intersection,** or simply their **intersection.**

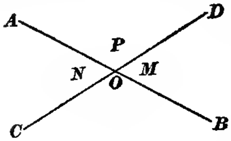


FIG. 19

29. Two intersecting straight lines make four angles having a common vertex. Any one of these angles and the angle on the opposite side of both lines, as the angles M and N, Fig. 19, are called **vertical angles** with respect to each other. Vertical angles may also be defined as those having a common vertex and in which the sides of the one are the prolongations of the sides of the other.

Since M and N are each the supplement of P, they are equal to each other. Any angle is equal to its vertical angle.

30. **Parallel lines,** such as $A B$ and $C D$, Fig. 20, are straight lines that lie in the same plane and never meet, however far they are produced. Any two parallel lines have the same direction and are everywhere equally distant from each other.

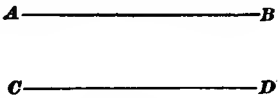


Fig. 20

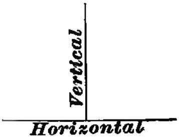


Fig. 21

31. A **horizontal line,** Fig. 21, is a line parallel to the horizon, or to the surface of still water.

32. A **vertical line,** Fig. 21, is a line perpendicular to a horizontal line.

33. In a drawing, it is usual to speak of lines drawn from left to right, or from right to left, as horizontal. In a diagram in a book, a line parallel to the printed lines is called a horizontal line, and a line perpendicular to the horizontal line is said to be vertical.

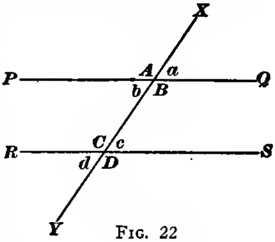


Fig. 22

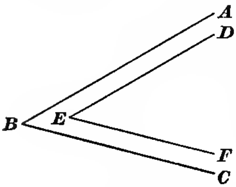


Fig. 23

34. When two parallel lines, as $P Q$ and $R S$, Fig. 22, are cut by a third line, as $X Y$, the angles denoted by the capital letters are equal to one another; that is, $A = B = C = D$. The angles designated by the small letters are also equal to one another: $a = b = c = d$.

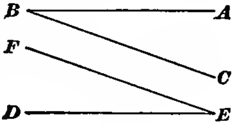


Fig. 24

35. If the corresponding sides of two angles are parallel and lie in the same or in opposite directions, the angles are equal. Thus, if the side $A B$, Fig. 23 or Fig. 24, is parallel to the side $D\,E$, and if the side $B\,C$ is parallel to the side $E\,F$, the angle E is equal to the angle B.

36. But if one of the sides of one angle lies in the same direction as the corresponding side of the other angle, and the other two corresponding sides lie in opposite directions, the angles are supplementary. Thus, in Fig. 25, $G\,H$ is parallel to and lies in the same direction as DE, and $H\,I$ is parallel to but lies in the opposite direction to $E\,F$; hence, the angle $G\,H\,I$ is the supplement of $D\,E\,F$.

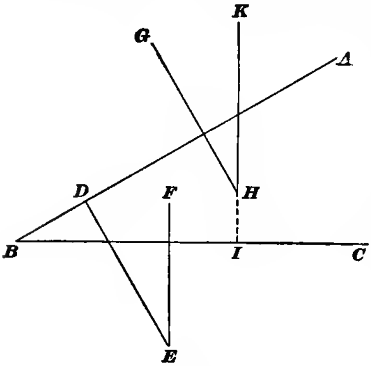


Fig. 25

37. If two sides of an angle are perpendicular to two sides of another angle, the two angles are either equal or supplementary. Thus, if $D\,E$ and $G\,H$, Fig. 25, are perpendicular to $B\,A$, and if $E\,F$ and $H\,K$ are perpendicular to $B\,C$, then angle E = angle B = angle $G\,H\,K$; also, $G\,H\,I$ is the supplement of $A\,B\,C$.

EXAMPLES FOR PRACTICE

1. In Fig. 26, find the number of degrees in the angle $E\,O\,A$. Ans. 156°

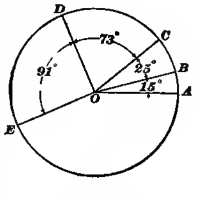


Fig. 26

2. In Fig. 26, find the number of degrees in the arc $A\,D$. Ans. 113°

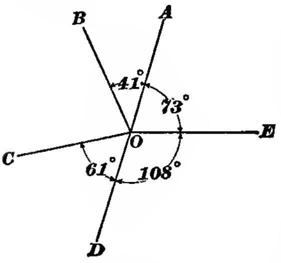


Fig. 27

3. In Fig. 27, find the number of degrees in the angle $B\,O\,C$. Ans. 77°

4. In a wheel with fourteen spokes spaced equal distances apart, what is the angle included between the center lines of any two adjacent spokes? Ans. $25\frac{5}{7}°$

5. If one straight line, as $O\,C$, Fig. 14, meets another straight line, as $A\,B$, so as to form an angle $A\,O\,C$ equal to 137°, what does its adjacent angle $C\,O\,B$ equal? Ans. 43°

6. If a number of straight lines meet a given straight line at a given point, all being on the same side of the given line, so as to form six equal angles, how many degrees are there in each angle? Ans. 30°

CONVERSION TABLES

38. In making calculations of various kinds, involving the lengths of lines, it may be desirable to find a dimension to the nearest hundredth of a foot, when it is stated in feet and inches; or, a dimension stated as a decimal may have to be expressed as a fraction of an inch. **Conversion tables,** as their name implies, are useful in converting, or changing, inches or fractions of an inch to decimals of a foot or inch, and for changing decimals to fractions. Table I gives the equivalents of inches and fractions of an inch in decimals of a foot, and Table II gives the equivalents of fractions of an inch in decimals of an inch.

TABLE I

INCHES TO DECIMALS OF A FOOT

Inches or Fractions	Decimal of Foot	Approximate Decimal	Inches	Decimal of Foot	Approximate Decimal
$\frac{1}{16}$	.0052	.005	3	.2500	.25
$\frac{1}{8}$	.0104	.010	4	.3333	.33
$\frac{1}{4}$	.0208	.020	5	.4167	.42
$\frac{3}{8}$	.0313	.030	6	.5000	.50
$\frac{1}{2}$	.0417	.040	7	.5833	.58
$\frac{5}{8}$	.0521	.050	8	.6667	.67
$\frac{3}{4}$	.0625	.060	9	.7500	.75
$\frac{7}{8}$	.0729	.070	10	.8333	.83
1	.0833	.080	11	.9167	.92
2	.1667	.170	12	1.0000	1.00

EXAMPLE 1.—Express 7 feet $8\frac{7}{8}$ inches in feet and a decimal of a foot.

SOLUTION.—From Table I, 8 in. = .67 ft., and $\frac{7}{8}$ in. = .07 ft.; hence,
7 ft. $8\frac{7}{8}$ in. $= 7 + .67 + .07 = 7.74$ ft. Ans.

EXAMPLE 2.—Express 18.19 feet in feet and inches.

SOLUTION.—By consulting the column of approximate decimals, Table I, it will be observed that .19 ft. is greater than .17 ft., or 2 in., and is less than .25 ft., or 3 in.; .19 being .02 greater than .17, .19 ft. equals 2 in. and .02 ft. more. According to the table, .02 ft. = $\frac{1}{4}$ in.; hence, .19 ft. = $2\frac{1}{4}$ in., and 18.19 ft. = 18 ft. $2\frac{1}{4}$ in. Ans.

TABLE II

FRACTIONS OF AN INCH TO DECIMALS OF AN INCH

Fraction of Inch	Exact Decimal of Inch	Approximate Decimal	Fraction of Inch	Exact Decimal of Inch	Approximate Decimal
$\frac{1}{32}$	.03125	.03	$\frac{9}{16}$	.5625	.56
$\frac{1}{16}$	.06250	.06	$\frac{5}{8}$	.6250	.63
$\frac{1}{8}$	.12500	.13	$\frac{11}{16}$	.6875	.69
$\frac{3}{16}$	.18750	.19	$\frac{3}{4}$	.7500	.75
$\frac{1}{4}$	.25000	.25	$\frac{13}{16}$	.8125	.81
$\frac{5}{16}$	.31250	.31	$\frac{7}{8}$	.8750	.88
$\frac{3}{8}$	.37500	.38	$\frac{15}{16}$	.9375	.94
$\frac{7}{16}$	.43750	.44	1	1.0000	1.00
$\frac{1}{2}$	.50000	.50			

Table II is used in a similar manner. Thus, 9.26 in. = $9\frac{1}{4}$ in., approximately.

PLANE FIGURES

CLASSIFICATION

39. A **plane figure** is any part of a plane surface bounded by straight or curved lines. When a plane figure is bounded by *straight lines*, it is called a **polygon.** The bounding lines are called the *sides*, and the length of the broken line that bounds it (or the whole distance around it) is called the **perimeter** of the polygon.

40. The angles formed by the sides are called the *angles* of the polygon. Thus, $A\,B\,C\,D\,E$, Fig. 28, is a polygon.

AB, BC, etc. are the sides; EAB, ABC, etc. are the angles; the points A, B, C, D, and E are the *vertexes* of the polygon; and the length of the broken line $ABCDEA$ is the perimeter.

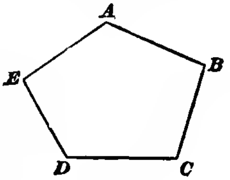


FIG. 28

41. Polygons are classified according to the number of their sides: A polygon of three sides is called a **triangle**; one of four sides, a **quadrilateral**; one of five sides, a **pentagon**; one of six sides, a **hexagon**; one of seven sides, a **heptagon**; one of eight sides, an **octagon**; one of ten sides, a **decagon**; one of twelve sides, a **dodecagon**; etc.

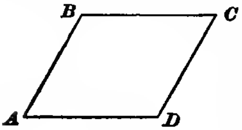


FIG. 29

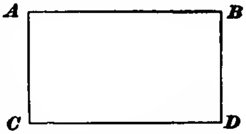


FIG. 30

42. **Equilateral polygons** are those in which the sides are all equal. Thus, in Fig. 29, $AB = BC = CD = DA$; hence, $ABDC$ is an equilateral polygon.

43. An **equiangular polygon** is a polygon whose angles are all equal. Thus, in Fig. 30, angle A = angle B = angle D = angle C; hence, $ABCD$ is an equiangular polygon.

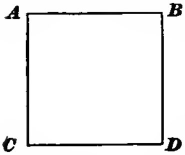
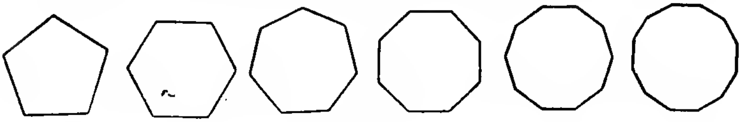


FIG. 31

44. A **regular polygon** is a polygon in which all the sides and all the angles are equal. Thus, in Fig. 31, $AB = BD = DC = CA$; and angle A = angle B = angle D = angle C; hence, $ABDC$ is a regular polygon. A regular polygon having four sides is called a *square*. Some other regular polygons, with their names, are shown in Fig. 32.



Pentagon Hexagon Heptagon Octagon Decagon Dodecagon

FIG. 32

TRIANGLES

45. According to the relative lengths of their sides, triangles are said to be *isosceles*, *equilateral*, or *scalene;* and according to the relative sizes of their angles they are said to be *right triangles* or *oblique triangles*.

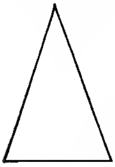


Fig. 33

46. An **isosceles triangle,** Fig. 33, is one having two of its sides equal.

47. An **equilateral triangle,** Fig. 34, is one that has its three sides equal.

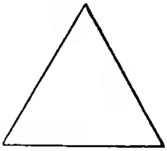


Fig. 34

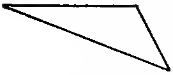


Fig. 35

48. A **scalene triangle,** Fig. 35, is one having no two of its sides equal.

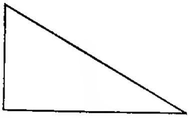


Fig. 36

49. A **right-angled triangle,** Fig. 36, is any triangle having one right angle. The side opposite the right angle is called the **hypotenuse;** when the *sides* of a right-angled triangle are referred to, the short sides are usually meant. For brevity, a right-angled triangle is termed a **right triangle.**

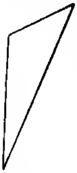


Fig. 37

50. An **oblique-angled,** or **oblique, triangle**, Fig. 37, is one that has no right angle. Thus, the isosceles, equilateral, and scalene triangles shown in Figs. 33 to 35 are also oblique triangles.

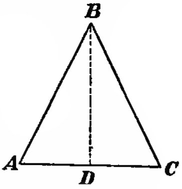


Fig. 38

51. The **base** of any triangle is the side on which the triangle is supposed to stand. A triangle may be drawn so as to stand on any side as the base.

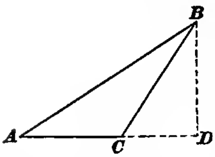


Fig. 39

The **altitude** of any triangle is a line drawn from the vertex of the angle opposite the base perpendicular to the base, or to the base extended. Thus, in Figs. 38 and 39, if the side *A C* is the base of the triangle, the line $B\,D$ is the altitude, which, in Fig. 39, is drawn to the base $A\,C$ extended to D. In a right triangle, as in Fig. 36, if one of the short sides is taken as the base, the other short side will be the altitude of the triangle.

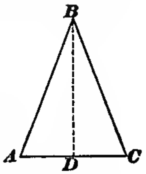


FIG. 40

52. In an isosceles triangle, the angles opposite the equal sides are equal. Thus, in Fig. 40, $A\,B = B\,C$; hence, angle C = angle A.

In any isosceles triangle, if a perpendicular is drawn from the vertex opposite the unequal side to that side, it bisects (cuts in halves) the side. Thus, in the isosceles triangle $A\,B\,C$, Fig. 40, the line $B\,D$, drawn from the vertex B opposite the unequal side $A\,C$ perpendicular to that side, divides it into two equal parts $A\,D$ and $D\,C$.

Similarly, in an isosceles triangle, if a line is drawn from the middle point of the unequal side to the vertex of the angle opposite, it will divide that angle into two equal parts, or bisect it. Thus, if D is the middle point of $A\,C$ in the isosceles triangle $A\,B\,C$, and $D\,B$ is drawn, the angle $A\,B\,D$ will equal the angle $D\,B\,C$ and each will be half of the angle $A\,B\,C$. The line $D\,B$ divides the triangle into two equal right triangles $A\,D\,B$ and $C\,D\,B$.

If two angles of any triangle are equal, the triangle is isosceles, and the sides opposite the equal angles are of equal lengths.

53. In any triangle, the sum of the three angles is equal to two right angles, or 180°. Thus, in Fig. 41, the sum of the angles at A, B, and C = two right angles; that is, $A+B+C = 180°$. Hence, if any two angles of a triangle are given, the third may be found by subtracting the sum of the two from 180°.

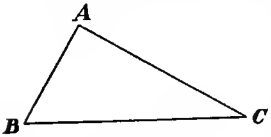


FIG. 41

EXAMPLE.—If, in Fig. 41, $A = 90°$ and $C = 35°$, how many degrees are there in B?

SOLUTION.—Since the sum of A, B, and C is 180°, B is equal to the difference between 180° and the sum of A and C. Therefore,

$$B = 180° - (90° + 35°) = 180° - 125° = 55°. \quad \text{Ans.}$$

54. In any right triangle there can be but one right angle; and since the sum of all the angles equals two right angles, it is evident that the sum of the two acute angles must be equal to a right angle. Therefore, if in any right triangle one acute angle is known, the other can be found by subtracting the known angle from 90°. Thus, $A\ B\ C$, Fig. 42, is a right triangle, right angled at C. Then, angle $A +$ angle $B =$ one right angle $= 90°$. If $A = 40°30'$, $B = 90° - 40°30' = 49°30'$.

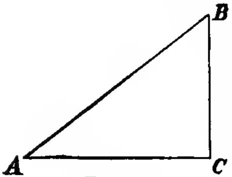


FIG. 42

If an isosceles triangle has one angle a right angle, each of the other two angles is 45°. Thus, if $A\ C$ and $B\ C$ were equal, the angles A and B would each be 45°.

55. Isosceles triangles and right triangles are met with very frequently in carpentry and in other forms of building construction. For example, Fig. 43 shows the outline of a common gable on a house. The lines $A\ B$ and $B\ C$ represent the rafters that support the roof and $B\ D$ represents the height of the gable above the base $A\ C$. As the rafters are of the same length on both sides of the roof, $A\ B = B\ C$, and so the triangle $A\ B\ C$ representing the gable is an isosceles triangle.

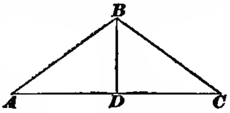


FIG. 43

The line $B\ D$, representing the height of the gable, is a perpendicular from B to $A\ C$. According to the statements made in Art. **52**, therefore, it bisects $A\ C$ and divides the triangle $A\ B\ C$ into two equal right triangles $A\ D\ B$ and $C\ D\ B$. In other words, $A\ D = D\ C$, and the angle $A\ B\ D$ is equal to the angle $C\ B\ D$. As $A\ B\ C$ is an isosceles triangle, the angles A and C are equal.

56. Carpenters give special names to the various dimensions of a gable. For instance, the height $B\ D$, Fig. 43, is called the *rise*. The distance $A\ D$ from the point A to the foot of a plumb-line dropped from B, or to D, is called the *run*. As $C\ D = A\ D$, the run is also represented by $C\ D$. The total width $A\ C$, which is twice the run, is called the *span*.

The slope of the roof depends on the relative height *B D* and width *A C*. The greater the rise, or height, for a given span, or width, the steeper becomes the slope, or *pitch*, of the roof. The pitch is the ratio of the rise to the span; thus, if the rise *B D* is 8 feet and the span, or width, *A C* is 24 feet, the pitch is $\frac{8}{24}=\frac{1}{3}$.

57. Another example of the occurrence of triangles in building work is found in the roof truss, which is a frame built to support a roof. The outline of a simple form of truss is shown in Fig. 44. The distance *A C* represents the span of the roof from wall to wall of the building, *B A* and *B C* are the parts corresponding to the rafters, and *B D* is the rise, or height, of the roof. The lines *D E* and *D F* indicate braces that stiffen and strengthen the truss.

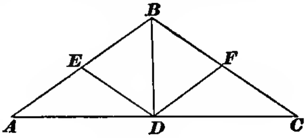


FIG. 44

EXAMPLES FOR PRACTICE

1. Find the number of degrees in each of the angles *B* and *C* of the triangle *A B C*, Fig. 45. Ans. $\left\{\begin{array}{l} B=36^\circ \\ C=108^\circ \end{array}\right.$

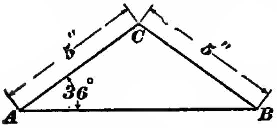


FIG. 45

2. How many degrees are there in each of the acute angles of an isosceles right triangle? Ans. 45°

3. One of the acute angles of a right triangle contains 30°. How many degrees are there in the other acute angle? Ans. 60°

4. In the roof truss, shown in Fig. 44, angle $A=35^\circ$ and $A\,E=E\,B=E\,D$. Find the number of degrees in the angles *A E D*, *E D A*, and *A B D*. Ans. $\left\{\begin{array}{l} A\,E\,D=110^\circ \\ E\,D\,A=35^\circ \\ A\,B\,D=55^\circ \end{array}\right.$

5. In a gable like that shown in Fig. 43, the span *A C* is 18 feet and the rise *B D* is 6 feet. What is the pitch, or slope? Ans. $\frac{1}{3}$

PRINCIPLE OF RIGHT TRIANGLE

58. A very important principle, and one that is applied in the solution of a great variety of problems, is the following: In every right triangle, the square formed on the hypotenuse is equal to the sum of the squares formed on the other two sides. This is clearly shown in Fig. 46, in which $A\,B\,C$ is a right triangle with its right angle at B. For convenience, the sides of the triangle are taken to represent 3, 4, and 5 feet, as indicated by the figures. The hypotenuse $A\,C$ forms one side of a square $A\,C\,E\,D$; the side $A\,B$ forms one side of a square $A\,B\,I\,K$; and the side $B\,C$ forms one side of a square $B\,C\,H\,F$. By dividing each of these squares into smaller squares of equal sizes, it will be seen that there are 25 small squares in $A\,C\,E\,D$, 16 in $B\,C\,H\,F$, and 9 in $A\,B\,I\,K$; in other words, the square $ACED$ on the hypotenuse contains as many smaller squares as the squares $A\,B\,I\,K$ and $B\,C\,H\,F$ together, or, $25=9+16$. This principle may be stated in another way by saying that the square of the length of the hypotenuse is equal to the sum of the squares of the other two sides. In the illustration, the square of the short side is $3^2=9$ and of the long side is $4^2=16$, and the square of the hypotenuse is $5^2=25$, which is equal to $9+16$; hence, $3^2+4^2=5^2$.

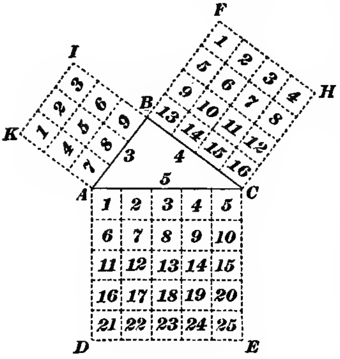


FIG. 46

According to this principle, if the lengths of the sides $A\,B$ and $B\,C$ are known, the length of the hypotenuse can be found by adding the squares of the lengths of the sides $A\,B$ and $B\,C$, and then extracting the square root of the sum.

Rule.—*To find the hypotenuse of a right triangle, add together the squares of the sides and extract the square root of the sum.*

Stated as a formula, this rule becomes

$$c = \sqrt{a^2+b^2}$$

in which c = length of hypotenuse;
a = length of one short side;
b = length of other side.

Example 1.—In Fig. 47, $B\ C$ is a brace joining the two pieces $A\ B$ and $A\ C$, which are perpendicular to each other. Find the length of $B\ C$, B being 24 inches from A, and C 36 inches from A.

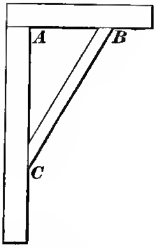


Fig. 47

Solution.—$A\ B\ C$ is a right triangle, of which $A\ B$ and $A\ C$ are the sides and $B\ C$ the hypotenuse. The length of $B\ C$ is found by adding the squares of the lengths of $A\ B$ and $A\ C$ and extracting the square root of the sum. Thus, the square of $A\ B$ equals

$$24^2 = 24 \times 24 = 576$$

The square of $A\ C$ is

$$36^2 = 36 \times 36 = 1{,}296$$

The sum of these squares is $576+1{,}296=1{,}872$; the square root of $1{,}872=43.27$. The length of $B\ C$ is therefore 43.27 in., or $43\frac{1}{4}$ in., approximately. Ans.

Example 2.—In a gable like that shown in Fig. 43, the span $A\ C$ is 20 feet and the height $B\ D$ is 10 feet. What is the length of the rafter $A\ B$?

Solution.—Since D is the middle point of $A\ C$, $A\ D=\frac{1}{2}\ A\ C=10$ ft. By Art. **52**, $A\ D\ B$ is a right triangle. Therefore, the square of the hypotenuse $A\ B$ is equal to the sum of the squares of the sides $A\ D$ and $B\ D$. As $A\ D=10$ ft. and $B\ D=10$ ft., $\overline{A\ D}^2=100$ and $\overline{B\ D}^2=100$. Then, $\overline{A\ B}^2=100+100=200$, and $A\ B=\sqrt{200}=14.14$ ft., or 14 ft. $1\frac{11}{16}$ in. Ans.

59. When one side and the hypotenuse of a right triangle are known, the other side may be found by applying the following rule:

Rule.—*To find one side of a right triangle when the other side and the hypotenuse are known, subtract the square of the given side from the square of the hypotenuse and extract the square root of the difference.*

Using letters having the same meaning as those given in the formula of Art. **58**, this rule may be stated thus:

$$a = \sqrt{c^2-b^2} \text{ or } b = \sqrt{c^2-a^2}$$

Example 1.—It is desired to find the height of the ceiling in a room. When one end of a 10-foot pole is set in the angle of the ceiling and wall, the other end is 6 feet from the base of the wall. What is the height of the ceiling?

Solution.—As the wall is at right angles to the ceiling and to the floor, the 10-ft. pole occupies the position $A\,B$, Fig. 48, with its lower end B at a distance of 6 ft. from C. As the line $A\,C$ where the walls meet is perpendicular to the floor, $A\,C\,B$ is a right triangle with its right angle at C, and so $A\,B$ is the hypotenuse. Call the hypotenuse c and the sides a and b, as shown. Then, according to the formula just given, $b=\sqrt{c^2-a^2}$. But, $c^2=10^2=100$, and $a^2=6^2=36$. Then,

$$b=\sqrt{100-36}=\sqrt{64}=8 \text{ ft.}$$

Therefore, the height of the ceiling is 8 ft. Ans.

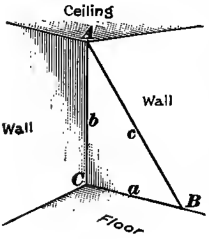


Fig. 48

Example 2.—The length of each of the equal sides of an isosceles triangle is 10 inches, and the length of the base is 12 inches; find the length of the perpendicular from the vertex to the base.

Solution.—Let $A\,B\,C$, Fig. 49, be the isosceles triangle. Then, $A\,D$ is one-half of the base; therefore, $A\,D=6$ in. In the right triangle $A\,C\,D$, the side $C\,D$ is equal to the square root of the remainder obtained by subtracting the square of the side $A\,D$ from the square of the hypotenuse $A\,C$. Hence,

$$C\,D=\sqrt{10^2-6^2}=\sqrt{64}=8 \text{ in. Ans.}$$

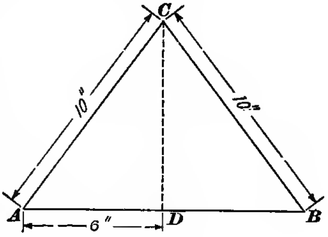


Fig. 49

60. The hypotenuse of a right triangle whose sides are of equal length is equal to the square root of twice the square of a side. $A\,B\,C$, Fig. 50, is a right triangle, the side $A\,B$ being equal to the side $B\,C$; then,

$$A\,C=\sqrt{2\times\overline{A\,B}^2}=1.4142\,A\,B$$

Rule.—*The hypotenuse of a right triangle having equal sides is equal to 1.4142 times the length of a side.*

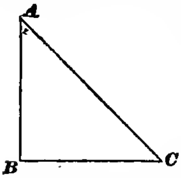


Fig. 50

Note.—In practice, when great accuracy is not required, $1\frac{5}{12}$ is sometimes used instead of 1.4142, as given in the foregoing rule. For example, when each side is 12 inches the hypotenuse is practically $1\frac{5}{12}\times12=17$ inches.

Example.—What is the length of a rafter, if the rise is 15 feet, and the span is 30 feet?

SOLUTION.—Since the rise DG, Fig. 51, is equal to one-half of the span, $DG = \frac{1}{2}EF = EG$. The length ED of the rafter is therefore the hypotenuse of a right triangle whose sides are equal.

$EG = \frac{1}{2}$ of $30 = 15$ ft.
$ED = 1.4142 \times 15 = 21.21$ ft.
.21 ft. $= .21 \times 12 = 2.52$ in. $= 2\frac{1}{2}$ in., nearly

Therefore, the length of the rafter is 21 ft. $2\frac{1}{2}$ in. Ans.

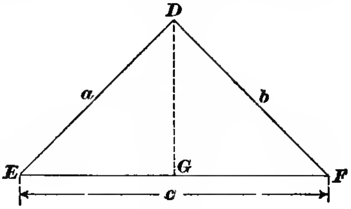


FIG. 51

The diagonal of a square is the hypotenuse of a right triangle having equal sides; hence, the diagonal of a square is equal to 1.4142 times the side of the square. The side of a square can be obtained when the diagonal is known by dividing the diagonal by 1.4142, or by multiplying the diagonal by .7071.

61. A right angle can be laid off by the following method, when the three sides of any right triangle are known: Suppose that AB, Fig. 52, is to be one line of the foundation of a building and it is desired to lay off from A another line that will make a right angle with AB.

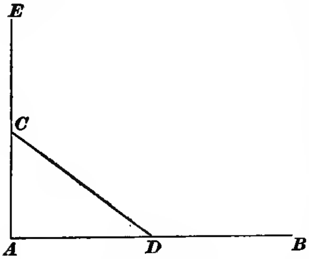


FIG. 52

It is known that a triangle whose sides are respectively 6, 8, and 10 feet is a right triangle, since $6^2 + 8^2 = 10^2$. On AB lay off AD equal to 8 feet. Fasten one end of a tape, or line, at A and draw the other end toward E, so that AE will be as nearly perpendicular to AB as can be estimated by the eye. Make AC on AE 6 feet. Measure the distance CD; if this is more or less than 10 feet, swing the line AE to the right or left, as may be necessary, until DC is exactly 10 feet, when the angle at A will be a right angle.

Any distances that will form three sides of a right triangle may be used in the preceding method; the numbers 3, 4, and 5, or some multiple, as 6, 8, and 10, or 9, 12, and 15, are most convenient.

62. The principle of the right triangle is of very great value in practical work, and the student should become thoroughly familiar with it in all of its variations.

The following is an example showing a double application of the right-triangle principle:

EXAMPLE.—The outline in Fig. 53 represents a skylight with a four-sided roof, each side in the form of an isosceles triangle. The length of the base $A\,D$ is 9 feet and the width $C\,D$ is 7 feet 6 inches. The point O is 2 feet above the plane of $A\,B\,C\,D$. What is the length of the edge $O\,D$ at the angle of the skylight?

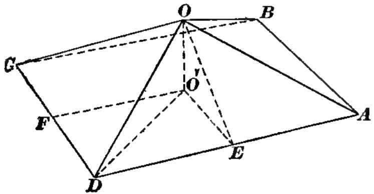


FIG. 53

SOLUTION.—It will be seen that the point O' is directly under O and 2 ft. below it, so that O' is on the same level as $A\,B\,C\,D$. It will also be seen that $D\,O$ is simply the hypotenuse of a right triangle, whose base is $D\,O'$ and whose altitude is $O\,O'$. But $D\,O'$ is also the hypotenuse of a right triangle, whose sides are $E\,O'$ and $E\,D$. $E\,O'$ is one-half of 7 ft. 6 in., or 3.75 ft., and $E\,D$ is one-half of 9 ft., or 4.5 ft. Then,

$$(D\,O')^2 = 3.75^2 + 4.5^2 = 34.3125$$

$$D\,O' = \sqrt{34.3125} = 5.86 \text{ ft.}$$

$$(D\,O)^2 = (D\,O')^2 + (O\,O')^2 = 34.3125 + 4 = 38.3125$$

$$D\,O = \sqrt{38.3125} = 6.19 \text{ ft.} = 6 \text{ ft. } 2\tfrac{1}{4} \text{ in., nearly. Ans.}$$

SIMILAR FIGURES

63. Similar polygons are those whose corresponding angles are equal and whose corresponding sides are proportional. In the quadrilaterals $A\,B\,C\,D$ and $A''\,B''\,C''\,D''$, Fig. 54, the corresponding angles are equal; that is, angle A equals angle A''; angle B equals angle B''; angle C equals angle C''; and angle D equals angle D'' Moreover, the corresponding sides of the figures are proportional; that is, $A''\,B''$ bears the same ratio to $A\,B$ as does $B''\,C''$ to $B\,C$, $C''\,D''$ to $C\,D$, and $D''\,A''$ to $D\,A$. The quadrilaterals $A\,B\,C\,D$ and $A''\,B''\,C''\,D''$ are therefore similar.

The quadrilaterals $A\,B\,C\,D$ and $A'\,B'\,C'\,D'$ have their corresponding angles equal, but the figures are not similar, since the corresponding sides are not proportional. For example, *A′ D′* does not bear the same ratio to *A D* as does *A′ B′* to *A B*.

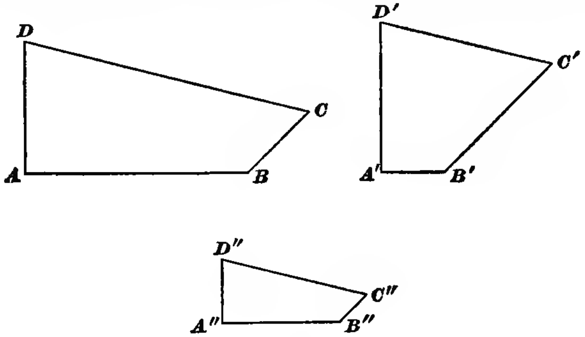


Fig. 54

64. Two triangles are similar when the angles of one are equal to the angles of the other. In the triangles *A B C* and *A′ B′ C′*, Fig. 55, angle *A* equals *A′*, angle *B* equals *B′*, and angle *C* equals angle *C′*; the triangles are therefore similar, and their corresponding sides are proportional.

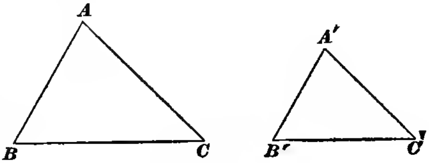


Fig. 55

65. Triangles that have their corresponding sides parallel are similar; for, the sides of the triangles are the sides of the angles, and it was shown in Art. **35** that if the sides of two angles are parallel, the angles are equal. In Fig. 55, *A B* is parallel to *A′ B′*, and *B C* to *B′ C′*, and *A C* to *A′ C′*; therefore, the angles *A*, *B*, and *C* are equal to *A′*, *B′*, and *C′*, respectively, and the triangles are similar.

The following are some of the proportions that may be formed from these similar triangles:

$$
\begin{aligned}
AB &: A'B' = AC : A'C' \\
AB &: A'B' = BC : B'C' \\
AC &: A'C' = BC : B'C' \\
AB &: BC = A'B' : B'C'
\end{aligned}
$$

EXAMPLE.—In Fig. 55, $A\,B=6$ feet, $A\,C=7$ feet, $B\,C=8$ feet, and $B'\,C'=6$ feet; find $A'\,B'$ and $A'\,C'$.

SOLUTION.—It will be observed that the lengths of the similar sides $B\,C$ and $B'\,C'$ are given, the ratio between their lengths being $8:6$, or $\frac{8}{6}$. The ratio between other similar sides will be the same; that is, $\frac{A\,B}{A'\,B'}=\frac{8}{6}$, and $\frac{A\,C}{A'\,C'}=\frac{8}{6}$. Since

$$A\,B : A'\,B' = 8 : 6, \text{ or } 6 : A'\,B' = 8 : 6$$

$$A'\,B' = \frac{6\times 6}{8} = 4\tfrac{1}{2} \text{ ft.} = 4 \text{ ft. } 6 \text{ in.} \quad \text{Ans.}$$

Again, $A\,C : A'\,C' = B\,C : B'\,C'$, or $7 : A'\,C' = 8 : 6$

Then, $$A'\,C' = \frac{7\times 6}{8} = 5\tfrac{1}{4} \text{ ft.} = 5 \text{ ft. } 3 \text{ in.} \quad \text{Ans.}$$

66. If a straight line is drawn through two sides of a triangle parallel to the third side, it divides those sides proportionally. Thus, let the line $D\,E$ be drawn parallel to the side $B\,C$ in the triangle $A\,B\,C$, Fig. 56. Then, $A\,D : A\,B = A\,E : A\,C$, or $A\,D : DB = A\,E : E\,C$. It is to be noticed that the triangles $A\,D\,E$ and $A\,B\,C$ are similar, and their sides are proportional. Thus $A\,B : A\,D = B\,C : D\,E$, and $A\,C : A\,E = B\,C : D\,E$.

If a straight line, as $D\,F$, is drawn from D, parallel to $A\,C$, the triangles $A\,D\,E$, $A\,B\,C$, and $D\,B\,F$ are all similar, and a number of other proportions may be formed.

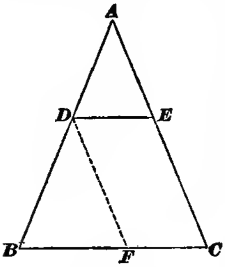


FIG. 56

EXAMPLE 1.—In Fig. 57, $D\,E$ is parallel to $B\,C$, and $A\,D$ is one-third of $A\,B$; find the length of $A\,E$.

SOLUTION.—Since $D\,E$ is parallel to $B\,C$, $A\,D : A\,B = A\,E : A\,C$. But, $A\,D : A\,B = 1 : 3$; then, $A\,E : A\,C = 1 : 3$. Substituting for $A\,C$ its value, $A\,E : 7 = 1 : 3$; hence

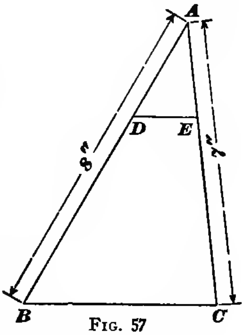


FIG. 57

$$A\,E = \frac{7\times 1}{3} = 2\tfrac{1}{3} \text{ in.} \quad \text{Ans.}$$

EXAMPLE 2.—On a drawing, it is required to divide a line 8 inches long into twelve parts.

SOLUTION.—The principle of similar triangles is very useful in solving an example of this kind. Let $A\,B$, Fig. 58, be the line 8 in. long that is to be divided into 12 equal parts. Obviously, each part will be $8 \div 12 = \frac{2}{3}$ in.; but the usual scales and rules are not graduated in thirds, and so they cannot be used. So, from one end A of $A\,B$ draw a line $A\,C$ at an acute angle to $A\,B$. The size of the angle is not important. From A to C lay off twelve equal distances, as, for example, twelve equal spaces of 1 in. each, which can be done readily with a scale or ruler. Join C and B by a straight line $C\,B$. Then, from the points of division on $A\,C$, draw lines parallel to $B\,C$, and these lines will divide $A\,B$ into twelve equal parts of $\frac{2}{3}$ in. each.

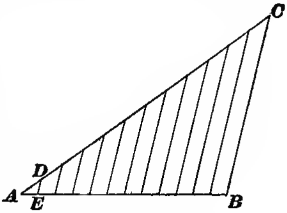


FIG. 58

The proof is quite simple. The lines parallel to $B\,C$ form a series of triangles similar to $A\,B\,C$, and their corresponding sides are therefore proportional. For example, the triangle $A\,E\,D$ is similar to $A\,B\,C$, and so $A\,E : A\,D = A\,B : A\,C$. But, $A\,D = 1$ in., $A\,B = 8$ in., and $A\,C = 12$ in. Hence, substituting these values, $A\,E : 1 = 8 : 12$, or $A\,E = \frac{1 \times 8}{12} = \frac{2}{3}$ in.

The equal spaces on $A\,C$ may be any convenient length instead of 1 in.; for example, they may be $\frac{1}{2}$ in. each, or $\frac{3}{4}$ in. or $\frac{7}{8}$ in., or any other length. The result will be the same in any case.

EXAMPLES FOR PRACTICE

1. A ladder 65 feet long reaches to the top of a house when its foot is 25 feet from the house. How high is the house, supposing the ground to be level? Ans. 60 ft.

2. In a triangle $A\,B\,C$, side $A\,B = 32$ feet, $B\,C = 34$ feet, and $A\,C = 48$ feet. If side $A\,B$ of a similar triangle is 72 feet long, what are the lengths of the other two sides? Ans. $\begin{cases} A\,C = 108 \text{ ft.} \\ B\,C = 76 \text{ ft. } 6 \text{ in.} \end{cases}$

3. The base of a right triangle is 24 inches, and its altitude, 72 inches. At what distance from the top is the triangle 16 inches wide? Ans. 48 in.

4. What length of rafter is required for each side of a gable, if the span is 24 feet, and the rise is three-fourths the span? Ans. 21 ft. $7\frac{1}{2}$ in.

5. $ABCD$, Fig. 59, is the outline of a roof. It is desired to extend the sides AB and CD to the ridge E. What are the distances EF and EA?

Ans. $\begin{cases} EF = 7 \text{ ft. } 6 \text{ in.} \\ EA = 22.41 \text{ ft., or } 22 \text{ ft. } 5 \text{ in., nearly} \end{cases}$

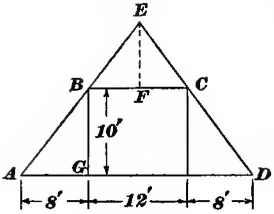


Fig. 59

6. What is the distance between the 16-inch mark on the body of a steel square, Fig. 7, and the 12-inch mark on the tongue?

Ans. 20 in.

7. The distance EB, Fig. 60, is $8\frac{1}{3}$ feet. If the distance between the pieces parallel to AB, measured from center to center, is 20 inches, and the length of AB is 5 feet 6 inches, what is the length of the piece CD?

Ans. 3 ft. $3\frac{3}{5}$ in.

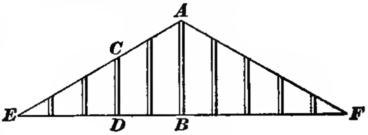


Fig. 60

GEOMETRICAL PRINCIPLES OF THE CIRCLE

67. A **chord** is a straight line joining any two points in a circumference; or, it is a straight line joining the extremities of an arc. Thus, in Fig. 61, AB is the chord of the arc AEB.

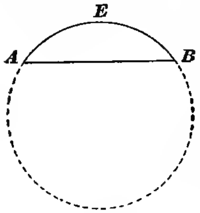


Fig. 61

68. A **segment** of a circle is the space included between an arc and its chord. Thus, in Fig. 61, the space between the arc AEB and the chord AB is a segment.

69. A **sector** of a circle is the space included between an arc and two radii drawn to the extremities of the arc. Thus, in Fig. 62, the space included between the arc AB and the radii OA and OB is a sector of the circle.

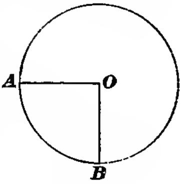


Fig. 62

70. Two circles are equal when the radius or diameter of one is respectively equal to the radius or diameter of the other.

Two arcs are equal when the radius and chord of one are equal to the radius and chord of the other.

71. An **inscribed angle** is one whose vertex lies on the circumference of a circle, and whose sides are chords. It is measured by one-half the intercepted arc. Thus, in Fig. 63, *A B C* is an inscribed angle, and it is measured by one-half the arc *A D C*.

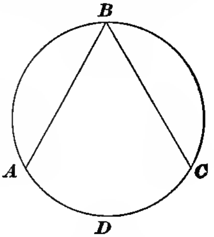


FIG. 63

EXAMPLE.—If, in Fig. 63, the arc *A D C* contains 144°, what is the measure of the inscribed angle *A B C*?

SOLUTION.—Since the angle is an inscribed angle, it is measured by one-half the intercepted arc, or

$\frac{1}{2} \times 144° = 72°$. Ans.

72. All angles inscribed in the same segment are equal. Thus, in Fig. 64, the inscribed angles *A B E*, *A C E*, and *A D E* are all equal; for each is measured by one-half of the arc *A E*.

For example, if the arc *A E* is 86°, each of the angles *A B E*, *A C E*, and *A D E* is equal to one-half of 86°, or 43°. It is thus seen that the angles *A B E*, *A C E*, and *A D E* are each equal to one-half of the angle *A O E*, which is formed by drawing radii from the center of the circle *O* to *A* and *E*.

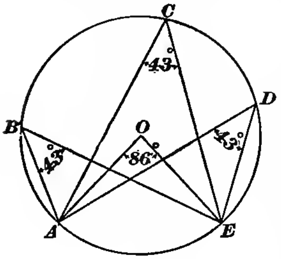


FIG. 64

Any angle inscribed in a semicircle is a right angle. Thus, the angle *A C B*, Fig. 65, is a right angle, for it is measured by one-half of the semicircumference *A D B*, and one-half of a semi-circumference is a quadrant, or 90°.

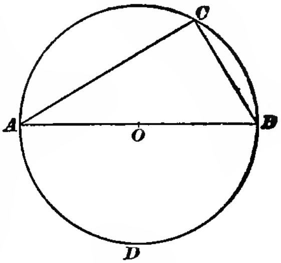


FIG. 65

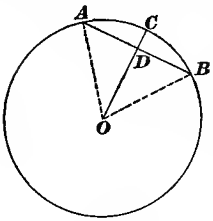


FIG. 66

73. If, in any circle, a radius is drawn perpendicular to any chord, it will bisect the chord. Thus, if the radius *O C*, Fig. 66, is perpendicular to the chord *A B*, then *A D* = *D B*.

A radius that bisects a chord, bisects also the angle included between radii drawn to the ends of the chord.

If a straight line is drawn perpendicular to any chord at its middle point, it must pass through the center of the circle.

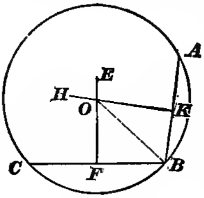


Fig. 67

74. Through any three points not in the same straight line, a circumference can be drawn. Let A, B, and C, Fig. 67, be any three points. Join A and B, also B and C, by straight lines. From the middle point of $A\,B$ draw $K\,H$ perpendicular to $A\,B$; from the middle point of $B\,C$ draw $F\,E$ perpendicular to $B\,C$. These two perpendiculars intersect at O. With O as a center, and $O\,B$, $O\,A$, or $O\,C$ as a radius, describe a circle; it will pass through A, B, and C.

75. A **tangent** to a circle is a straight line that touches the circle at one point only; it is always perpendicular to a radius drawn to that point. Thus, $A\,B$, Fig. 68, is a tangent to the circle; it touches the circle at E and is perpendicular to the radius $O\,E$.

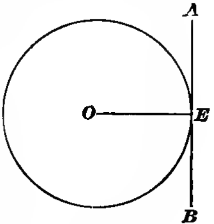


Fig. 68

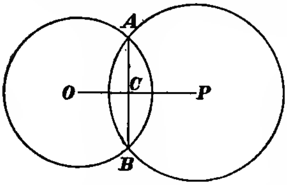


Fig. 69

76. If two circles intersect each other, the line joining their centers bisects at right angles the line joining the two points of intersection. Thus, if the two circles whose centers are O and P, Fig. 69, intersect at A and B, the line $O\,P$ bisects at right angles the line $A\,B$; or $A\,C = B\,C$.

77. One circle is said to be tangent to another circle when they touch each other at one point only, as in Fig. 70. This point is called the *point of contact*, or the *point of tangency.*

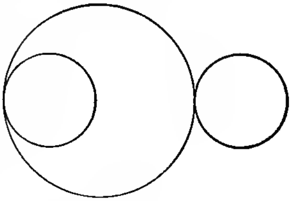


Fig. 70

78. When two or more circles are described from the same center, as in Fig. 71, they are called *concentric circles.*

79. If two chords of a circle intersect, the product of the segments (parts) thus formed of one of the chords is equal to the product of the segments of the other. Thus, $A\,B$ and $C\,D$, Fig. 72, are chords that intersect at E. Then,

$$A\,E \times E\,B = C\,E \times E\,D$$

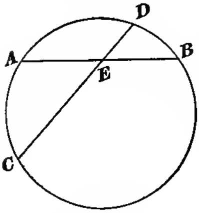


FIG. 72

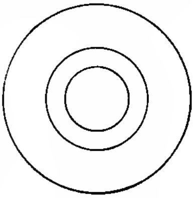


FIG. 71

EXAMPLE.—In Fig. 73, the diameter $B\,E$ of the circle is 29 feet, and the distance $B\,D$, 4 feet. What is the length of the chord $A\,C$ that passes through D and is perpendicular to $B\,E$?

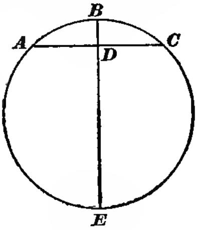


FIG. 73

SOLUTION.—Since $A\,C$ is perpendicular to the diameter $B\,E$, $B\,E$ bisects $A\,C$, and $A\,D = D\,C$ (Art. **73**).

$$D\,E = 29 - 4 = 25 \text{ ft.}$$

The products of the segments of the intersecting chords being equal, $A\,D \times D\,C = B\,D \times D\,E$. But, $A\,D = D\,C$; therefore,

$$\overline{A\,D}^2 = B\,D \times D\,E = 4 \times 25 = 100;$$

$$A\,D = \sqrt{100} = 10 \text{ ft.}$$

and $$A\,C = 2 \times A\,D = 2 \times 10 = 20 \text{ ft.}\quad \text{Ans.}$$

80. Since $\overline{A\,D}^2 = B\,D \times D\,E$, in Fig. 73, the following principle may be deduced from the preceding solution: When a chord, as $A\,C$, is drawn perpendicular to a diameter of a circle, as $B\,E$, the square of one-half the chord is equal to the product of the parts of the diameter formed by the intersection of the chord. Here the chord $A\,C$ is divided into two equal parts, $A\,D$ and $D\,C$, by the diameter $B\,E$. Then, $\overline{A\,D}^2$, as well as $\overline{D\,C}^2$, is equal to $B\,D \times D\,E$.

EXAMPLE.—If, in Fig. 73, $B\,D$ is 3 feet and $D\,E$ is 9 feet, find the length of the half-chord $A\,D$.

SOLUTION.— $\overline{A\,D}^2 = B\,D \times D\,E = 3 \times 9 = 27$. Since the square of $A\,D = 27$,

$$A\,D = \sqrt{27} = 5.20 \text{ ft., or 5 ft. } 2\tfrac{3}{8} \text{ in., approximately.}\quad \text{Ans.}$$

81. In the circle $A\,B\,C\,E$, Fig. 74, $A\,C$ is the chord of the segment $A\,B\,C$. $B\,D$ is the height of the segment; $B\,C$, the chord of one-half the arc; and $B\,E$, the diameter perpendicular to the chord. Then,

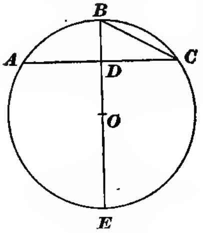


FIG. 74

$$\overline{B\,C}^2=\overline{B\,D}^2+\overline{D\,C}^2$$

But, $$\overline{D\,C}^2=B\,D\times D\,E$$

Therefore, $$\overline{B\,C}^2=\overline{B\,D}^2+B\,D\times D\,E$$

or, $$\overline{B\,C}^2=B\,D\,(B\,D+D\,E)$$

As $$B\,D+D\,E=B\,E,$$

$\overline{B\,C}^2=B\,D\times B\,E$, and $B\,E=\dfrac{\overline{B\,C}^2}{B\,D}$, or the radius $B\,O=\dfrac{\overline{B\,C}^2}{2\,B\,D}$

Rule.—*The radius of a circle is equal to the square of the chord of one-half of a given arc divided by twice the height of the segment.*

EXAMPLE.—Referring to Fig. 74, $B\,C=3$ feet 6 inches, and $B\,D=1$ foot 7 inches. Find the radius $B\,O$.

SOLUTION.— $B\,C=42$ in.; $B\,D=19$ in. According to the rule, the radius is

$$B\,O=\frac{\overline{B\,C}^2}{2\,B\,D}=\frac{42^2}{2\times 19}=46.42 \text{ in., or 3 ft. } 10\tfrac{7}{16} \text{ in., nearly. Ans.}$$

82. Where the chord of the arc and the height of the segment are known, to find the radius of the circle, add the square of one-half the chord to the square of the height of the segment and divide the sum by twice the height of the segment.

Let r = radius;
c = chord of arc;
h = height of segment.

Then, $$r=\frac{\left(\frac{c}{2}\right)^2+h^2}{2h}$$

or, $$r=\frac{c^2+4h^2}{8h}$$

Example.—In arches, the *span* is the distance across the opening, as $A\ C$, Fig. 75, measured from the ends of the arch, as A and C. The *rise* $D\ B$ is the perpendicular distance from $A\ C$ to the highest point B measured on the center line $O\ B$.

The span $A\ C$, Fig. 75, of an arch is 6 feet, and the rise $D\ B$ is 8 inches. What is the length of the radius $O\ B$?

Solution.—The span $A\ C$ is a chord of the arc $A\ B\ C$, and $B\ D$ is the height of the segment. $A\ D$, one-half of the chord, is $\frac{1}{2}\times 72$ in. $=36$ in.

$$O\,B=\frac{\overline{A\,D}^2+\overline{B\,D}^2}{2\,B\,D}=\frac{36^2+8^2}{2\times 8}=\frac{1360}{16}=85 \text{ in.}$$

Therefore, $O\,B=85$ in. $=7$ ft. 1 in. Ans.

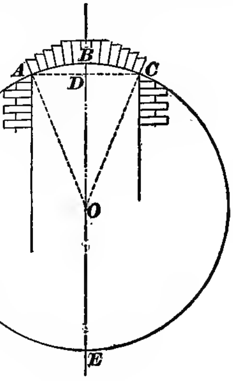


Fig. 75

INSCRIBED AND CIRCUMSCRIBED POLYGONS

83. An **inscribed polygon** is one whose vertexes lie on the circumference of a circle and whose sides are chords, as $K\ L\ M\ N\ P\ Q$, Fig. 76.

84. A **circumscribed polygon** is one whose sides are tangent to a circle, as $A\ B\ C\ D\ E\ F$, Fig. 76.

Circles may be inscribed in and circumscribed about any regular polygon. The radius of the circumscribed circle is the distance from the center to an angle of the inscribed polygon, and of the inscribed circle the perpendicular distance from the center to the side of the circumscribed polygon, as shown in Fig. 76.

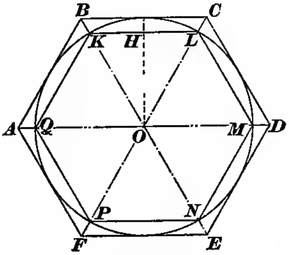


Fig. 76

85. If lines are drawn from the center to the angles of a regular polygon, they will make equal angles with the sides of the polygon and will form isosceles triangles. As the sum of all the angles formed about a point by lines drawn from it is equal to 360°, the angle at the center of a regular polygon between two radii equals 360° divided by the number of sides. Thus, the angle between two radii drawn to the ends of a side of a regular hexagon is $360° \div 6 = 60°$. The sum of the angles of a triangle is two right angles, or 180°; hence, since the triangles formed by drawing radii to the angles of a regular polygon are isosceles, the angles $O\,Q\,K$ and $O\,K\,Q$, Fig. 76, are each equal to one-half the difference between 180° and the central angle. Thus, each angle is $\frac{1}{2}\times(180°-60°)=60°$, and consequently the triangle $O\,K\,Q$ is equilateral. In a regular hexagon, therefore, the sides are equal to the radius of the circumscribed circle.

A line drawn from the center of a regular polygon to an angle bisects the angle; thus $O\,A$ bisects the angle $B\,A\,F$, which, therefore, is equal to $2\times O\,A\,B$, or $2\times O\,A\,F$.

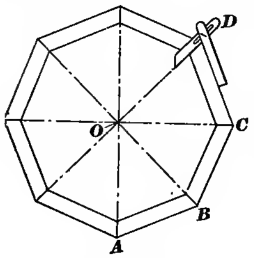


FIG. 77

86. The principles of Art. **85** are employed, in practice, to determine the various cuts of material used in the construction of regular polygons.

EXAMPLE 1.—Eight pieces of molding, as $A\,B$, $B\,C$, etc., Fig. 77, are to be laid around an octagonal room of equal sides, the ends of the pieces being sawed off at an angle so as to match, as shown. To what angle must a bevel, as shown at D, be set in order to mark the line of the saw cut?

SOLUTION.—Draw $A\,O$, $B\,O$, etc. to the center O, forming triangles $A\,O\,B$, $B\,O\,C$, etc. Then each of the angles at O is one-eighth of 360° $=45°$. The angles $O\,A\,B$ and $O\,B\,A$ are each

$$\tfrac{1}{2}\times(180°-45°)=67\tfrac{1}{2}°$$

If the blade of the bevel is set at this angle, as at D, and the ends of the pieces of molding are cut to it, they will fit together properly. Ans.

EXAMPLE 2.—In Fig. 78, $G\,H\,E\,F$ and $H\,K\,D\,E$ represent two boards forming a center for supporting a brick arch during building, the shaded parts being cut away, leaving a curve, as $A\,L\,B\,C$, on which to form the arch. What is (a) the length $G\,H$ (or $H\,K$) of each board, and (b) the angle of bevel $G\,H\,O$ where they meet? The radius $A\,O$ of the arch is 2 feet.

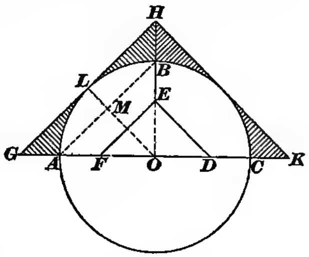


FIG. 78

SOLUTION.—(*a*) Draw AB parallel to GH and meeting OG and OH; also draw OL perpendicular to AB; then $AM=MB$ (Art. **73**), and by similar triangles, $LG=LH$. OL bisects the right angle AOB; hence, AOM is one-half of 90°, or 45°. Then the other acute angle in the right triangle OMA is $90°-45°=45°$ also. The angle LGO is equal to the angle MAO, or 45°, and the right triangle OLG having two angles equal, the opposite sides are equal also; and since OL = the radius, or 2 ft., LG is also 2 ft. and GH is $2\times2=4$ ft., the required length. Ans.

(*b*) Angle GHO = angle $OGH=45°$, the angle at which to set the bevel. Ans.

87. The following principle may also be conveniently used in many cases. In any polygon, the sum of all the angles equals 180° multiplied by a number that is two less than the number of sides in the polygon. Hence, to find the size of any one of the angles of a regular polygon, multiply 180° by the number of sides less two, and divide the result by the number of sides; the quotient will be the number of degrees in each angle. For example, each angle of a regular octagon, as in Fig. 77, is $[180\times(8-2)]\div8=135°$.

EXAMPLES FOR PRACTICE

1. The span of a circular arch is 7 feet, and the rise is 1 inch for each foot of span. What is the radius of the arch?

Ans. 10 ft. 9½ in.

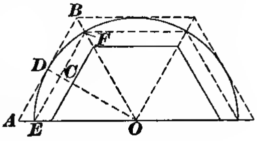


FIG. 79

2. The centering for an arch, Fig. 79, 8 feet in diameter, is made of three pieces of equal lengths. Knowing that the side of a regular inscribed hexagon is equal to the radius, what should be the length, as AB, of each piece?

Ans. 4.62 ft., or 4 ft. 7½ in., nearly

SUGGESTION.—Find the length of OC in the right triangle OCE; then by the similar triangles OEC and OAD find the length of AO. The proportion will be stated: $OC:OD=OE:OA$. AB will equal AO.

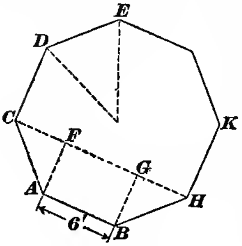


FIG. 80

3. In the preceding example, what is: (*a*) the bevel angle ABO? (*b*) the angle between any two adjacent pieces?

Ans. $\begin{cases}(a)\ 60°\\(b)\ 120°\end{cases}$

4. The flooring in a regular octagonal room, Fig. 80, is laid parallel to the side AB, which is 6 feet long. What is the angle of bevel for cutting the ends of the pieces that fit along AC?

Ans. 135° or 45°

5. What is the length of the pieces of flooring between the sides *C D* and *H K*, Fig. 80, knowing that *C F* and *A F* are equal and that the angle *C F A* is a right angle? (See Art. **60.**)

Ans. 14.48 ft., or 14 ft. $5\frac{3}{4}$ in., nearly

6. In Fig. 73, if the diameter of the circle is 10 feet and *D E* is 8 feet 6 inches, find the distance *D C*. Ans. 3 ft. $6\frac{7}{8}$ in., nearly

GEOMETRY AND MENSURATION

(PART 2)

FINDING AREAS AND VOLUMES

MENSURATION OF PLANE SURFACES

UNITS OF MEASUREMENT

1. The **area** of a figure means the extent of the surface included within the bounding lines of the figure, and is expressed by the number of unit squares it will contain.

2. A **unit square** is the square having the unit for its side. For example, if the unit is 1 inch, the unit square is the square whose side measures 1 inch in length. In measuring a surface, the area may be expressed by the number of square inches that the surface contains. If the unit were 1 foot, the unit square would measure 1 foot on each side, and a surface would then be measured by the number of square feet that it contained.

The square that measures 1 inch on a side is called a **square inch,** and the one that measures 1 foot on a side is called a **square foot.** Square inch and square foot are abbreviated to sq. in. and sq. ft., or are sometimes indicated by □″ and □′.

QUADRILATERAL

3. A **parallelogram** is a quadrilateral, or four-sided figure, whose opposite sides are parallel. There are four kinds of parallelograms: the *square*, the *rectangle*, the *rhombus*, and the *rhomboid*.

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4. A **rectangle,** Fig. 1, is a parallelogram whose angles are all right angles.

5. A **square,** Fig. 2, is a rectangle, all of whose sides are equal.

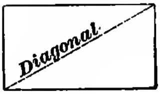


Fig. 1

6. A **rhomboid,** Fig. 3, is a parallelogram whose opposite sides only are equal, and whose angles are not right angles.

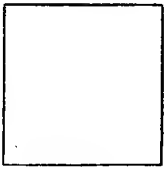


Fig. 2

7. A **rhombus,** Fig. 4, is a parallelogram having equal sides, and whose angles are not right angles.

Fig. 3

8. A **trapezoid,** Fig. 5, is a quadrilateral that has only two of its sides parallel.

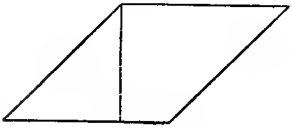


Fig. 4

9. A **trapezium,** Fig. 6, is a quadrilateral having no two sides parallel.

10. The **altitude** of a parallelogram, or of a trapezoid, is the perpendicular distance between the parallel sides. In Figs. 3 to 5, the altitude is indicated by a dotted vertical line.

Fig. 5

11. A **diagonal** is a straight line drawn from the vertex of any angle of a quadrilateral to the vertex of the angle opposite; a diagonal divides the quadrilateral into two triangles. A diagonal divides a parallelogram into two *equal* triangles.

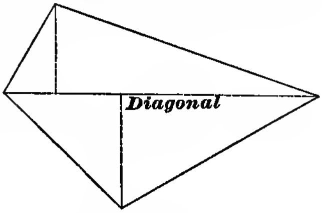


Fig. 6

12. The area of any parallelogram may be found by the following rule:

Rule.—*To find the area of any parallelogram, multiply the base by the altitude.*

Let A = area;
h = altitude;
b = base.

Then, $A = b\,h$

EXAMPLE 1.—What is the area of the rectangle $A\,B\,C\,D$, Fig. 7?

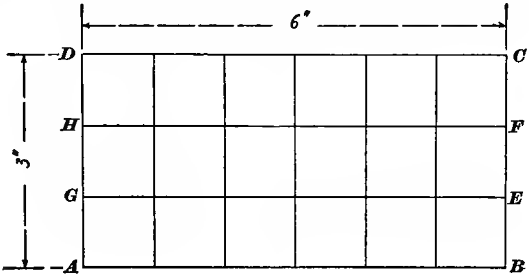


FIG. 7

SOLUTION.—The area of the rectangle equals the product of the base, which is 6 in., and the height, which is 3 in. Hence, the area is

$$6 \times 3 = 18 \text{ sq. in. Ans.}$$

NOTE.—By dividing Fig. 7 into squares as shown, it is seen that, if the figure is drawn full size, it will require 18 square inches to cover it.

EXAMPLE 2.—A rectangular lot is 4 rods wide and 8 rods long: (*a*) How many square feet does it contain? (*b*) What part of an acre is it?

SOLUTION.—(*a*) Reducing rods to feet, 4 rd. = 66 ft., and 8 rd. = 132 ft. Either side may be taken as the base. Apply the formula, and

$$A = b\,h = 66 \times 132 = 8{,}712 \text{ sq. ft. Ans.}$$

(*b*) As there are 43,560 sq. ft. in an acre, 8,712 sq. ft. = 8,712 ÷ 43,560 = .2 = $\frac{1}{5}$ A. Ans.

13. The area of a trapezoid may be found as follows:

Rule.—*To find the area of a trapezoid, multiply one-half the sum of the parallel sides by the altitude.*

Let a and b = lengths of parallel sides;
h = altitude.

Then, $$A = h\left(\frac{a+b}{2}\right)$$

EXAMPLE.—How many square feet of floor space are there in a five-story warehouse, if each floor has the dimensions given in Fig. 8?

Solution.—As either of the parallel sides may be called a, let it be the shorter; $a = 49$ ft. 6 in. $= 49.5$ ft.; $b = 54$ ft. 3 in. $= 54.25$ ft.; and $h = 27$ ft. 9 in. $= 27.75$ ft. Then, apply the formula, and

$$A = h\left(\frac{a+b}{2}\right) = 27.75\left(\frac{49.5+54.25}{2}\right) = 1{,}439.5 \text{ sq. ft.}$$

Therefore, the area of five such floors is $5 \times 1{,}439.5 = 7{,}197.5$ sq. ft. Ans.

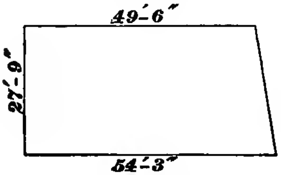
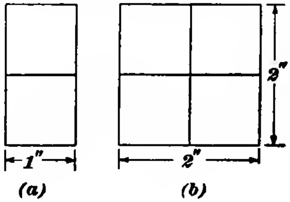


Fig. 8



(a) (b)

Fig. 9

14. It should be observed that *2 square inches* does not mean the same as *2 inches square; 3 square inches* does not mean the same as *3 inches square;* etc. Fig. 9 (a) shows a rectangle 2 inches by 1 inch, and its area is 2 square inches; (b) shows a square 2 inches by 2 inches; that is, a figure 2 inches square, and its area is 4 square inches.

TRIANGLE

15. The following rule may be employed in finding the area of a triangle:

Rule.—*To find the area of a triangle, multiply the base by the altitude and divide the product by 2.*

Let A = area;
b = base;
h = altitude.

Then, $$A = \frac{b\,h}{2}$$

The base and the altitude must always be stated in the same units; that is, both must be in inches, or both in feet, in which case the area found will be given in square inches, or square feet, respectively.

Example.—The triangular gable of a house is 24 feet wide and 12 feet high. What is its area?

SOLUTION.—The gable is a triangle having a base of 24 ft. and an altitude of 12 ft. Hence, according to the rule, the area is

$$A = (24 \times 12) \div 2 = 144 \text{ sq. ft.} \quad \text{Ans.}$$

16. If the triangle is a right triangle, one of the short sides may be taken as the base, and the other short side as the altitude; hence, *the area of a right triangle is equal to one-half the product of the two short sides.*

17. If the lengths of the three sides of a triangle are given, the area may be found. Call the three sides a, b, and c, and let s represent half the sum of the sides, or $s = \frac{1}{2}(a+b+c)$. Then the area A of the triangle may be found by the formula

$$A = \sqrt{s(s-a)(s-b)(s-c)}$$

In other words, each side is subtracted from half the sum of the three sides, and these three remainders are multiplied together and by half the sum of the sides, or s; then the square root of the product is the area.

EXAMPLE.—What is the area of a triangular plot of ground, the sides of the plot being 60, 55, and 35 feet, respectively?

SOLUTION.—It does not matter which side is called a, b, or c. Letting $a = 60$, $b = 55$, and $c = 35$,

$$s = \tfrac{1}{2}(60+55+35) = 75$$

Then,

$$s-a = 75-60 = 15$$
$$s-b = 75-55 = 20$$
$$s-c = 75-35 = 40$$

and

$$A = \sqrt{75 \times 15 \times 20 \times 40} = \sqrt{900{,}000} = 948.68 \text{ sq. ft.} \quad \text{Ans.}$$

POLYGONS

18. To find the area of any figure bounded by straight lines the following rule may be employed:

Rule.—*To find the area of any figure bounded by straight lines, divide the figure into triangles, parallelograms, and trapezoids, and find the area of each. The sum of these partial areas will be the area of the figure.*

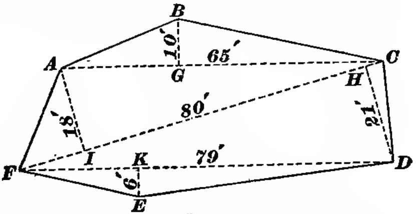


FIG. 10

Example.—A lot has the dimensions given in Fig. 10. How many square feet does it contain?

Solution.—The distances marked on Fig. 10 being measured. the partial areas are found to be:

$$\text{Triangle } A\,B\,C = \frac{65\times10}{2} = 325 \text{ sq. ft.}$$

$$\text{Triangle } F\,A\,C = \frac{80\times18}{2} = 720 \text{ sq. ft.}$$

$$\text{Triangle } F\,C\,D = \frac{80\times21}{2} = 840 \text{ sq. ft.}$$

$$\text{Triangle } F\,D\,E = \frac{79\times6}{2} = \underline{237 \text{ sq. ft.}}$$

$$2{,}122 \text{ sq. ft.}$$

The area of the lot is therefore the sum of these, or 2,122 sq. ft. Ans.

19. A regular polygon may be divided into as many equal triangles as the figure has sides by drawing lines from the center of the polygon to its angles. In Fig. 11, for example, the hexagon $A\,B\,C\,D\,E\,F$ is composed of six equal triangles, $A\,O\,B$, $B\,O\,C$, $C\,O\,D$, $D\,O\,E$, $E\,O\,F$, and $F\,O\,A$. The area of each triangle is equal to one-half of the product of a side and the altitude, which is the perpendicular distance $O\,G$ from the center to a side. The entire area of the polygon is therefore obtained by multiplying the area of one of these triangles by the number of triangles, or six; or, the area of a regular polygon is found by multiplying one-half the perimeter of the figure by the perpendicular distance from the center to a side.

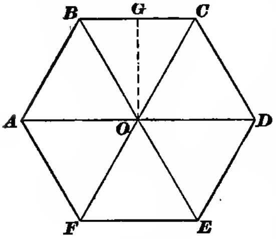


Fig. 11

Example.—What is the area of an octagonal room, each of whose eight sides is 9 feet, when the distance from the center of the room to a side is 10 feet 10½ inches?

Solution.—The perimeter is 8×9=72 ft.; 10 ft. 10½ in.=10.875 ft.

$$\text{Area} = \frac{10.875\times72}{2} = 391.5 \text{ sq. ft. Ans.}$$

20. The areas of regular polygons whose names are given in column B, of Table I, and whose sides are each 1,

TABLE I

TABLE OF REGULAR POLYGONS

Number of Sides	Name	Area, When Side = 1	Radius of Circumscribed Circle, When Side = 1	Side, When Radius of Circumscribed Circle = 1	Radius of Inscribed Circle, When Side = 1	Side, When Radius of Inscribed Circle = 1	Radius of Circumscribed Circle, When Radius of Inscribed Circle = 1	Angle at Each Vertex	One-Half of Angle at Vertex
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*
3	Triangle	.4330	.5773	1.7321	.2887	3.4641	2	60°	30°
4	Square	1	.7071	1.4142	.5	2	1.4142	90°	45°
5	Pentagon	1.7205	.8507	1.1756	.6882	1.4531	1.2361	108°	54°
6	Hexagon	2.5981	1	1	.8660	1.1547	1.1547	120°	60°
7	Heptagon	3.6339	1.1524	.8678	1.0383	.9632	1.1099	128° 34′	64° 17′
8	Octagon	4.8284	1.3066	.7654	1.2071	.8284	1.0824	135°	67° 30′
9	Nonagon	6.1818	1.4619	.6840	1.3737	.7279	1.0642	140°	70°
10	Decagon	7.6942	1.6180	.6180	1.5388	.6498	1.0515	144°	72°
11	Undecagon	9.3656	1.7747	.5635	1.7028	.5873	1.0422	147° 16′	73° 38′
12	Dodecagon	11.1962	1.9319	.5176	1.8660	.5359	1.0353	150°	75°

or unity, are found in column *C* opposite the corresponding name. For example, the area of a regular decagon each of whose sides is 1 foot is 7.6942 square feet. The areas of regular polygons mentioned in the table may be obtained as follows:

Rule I.—*To find the area of a regular polygon, multiply the square of the side by the number in column C standing opposite the name of the polygon in column B.*

Example 1.—What is the area of a regular twelve-sided figure, each of its sides being 9 feet long?

Solution.—The figure is a dodecagon, and the corresponding number in column *C* is 11.1962.

$$\text{Area} = 9 \times 9 \times 11.1962 = 906.89 \text{ sq. ft.} \quad \text{Ans.}$$

Rule II.—*To find the side of a regular polygon when the area is known, divide the area by the number in column C corresponding to the name of the polygon and extract the square root of the result.*

Example 2.—What is the side of a regular octagon that contains an area of 2,000 square feet?

Solution.—The number in column *C* to be used for an octagon is 4.8284. $2,000 \div 4.8284 = 414.22$. The square root of 414.22 is 20.35. Hence, 20.35 ft., or 20 ft. $4\frac{1}{4}$ in., nearly, is the length of the side. Ans.

21. In column *D* of Table I, are given the radii of the circles that may be described about the regular polygons named, when each side is of unit length. In column *E* are given the lengths of sides of inscribed polygons when the radius of the circle is 1, etc. The use of the various columns will be made clear by the following rules and illustrative examples:

Rule I.—*To find the radius of the circumscribed circle when the side of a regular polygon is known, multiply the side by the number in column D opposite the name of the polygon.*

Example 1.—It is required to lay out a regular seven-sided figure, each side being 2 feet. What is the radius of the circle whose circumference will pass through each corner of the figure?

Solution.—The number in column *D* opposite heptagon is 1.1524. Radius of circumscribed circle is

$$2 \times 1.1524 = 2.3048, \text{ or, } 2 \text{ ft. } 3\tfrac{5}{8} \text{ in., nearly.} \quad \text{Ans.}$$

Rule II.—*To find the length of the side of a regular polygon that may be inscribed in a circle of known radius, multiply the known radius by the number in column E opposite the name of the polygon.*

Example 2.—What is the length of the side of an octagon that may be inscribed in a circle 12 feet in diameter?

Solution.—Radius is 12÷2=6 ft. Number in column E opposite octagon is .7654. Length of side is

$6 \times .7654 = 4.5924$, or 4 ft. $7\frac{1}{8}$ in., nearly. Ans.

Rule III.—*To find the radius of the inscribed circle when the side of a regular polygon is known, multiply the side by the number in column F opposite the name of the polygon.*

Example 3.—It is desired to determine the perpendicular distance from the center of a regular nonagon to each of its sides, when the length of each side is 5 feet.

Solution.—The perpendicular distance from the center of the polygon to its sides is equal to the radius of the circle that may be inscribed in the polygon. The number in column F opposite nonagon is 1.3737; hence, perpendicular distance is

$5 \times 1.3737 = 6.8685$, or 6 ft. $10\frac{7}{16}$ in., nearly. Ans.

Rule IV.—*To find the side of a regular polygon when the radius of the inscribed circle is known, multiply the radius by the corresponding number in column G.*

Rule V.—*To find the radius of the circle circumscribed about a regular polygon when the radius of the inscribed circle is known, multiply the given radius by the corresponding number in column H.*

22. In column I of Table I, are found the angles of each vertex of a regular polygon formed by the adjacent sides.

In column J are found the values of one-half the angle at each vertex, or the angles that should be used in making the bevel cuts for moldings or material laid parallel to the sides, and jointed.

EXAMPLES FOR PRACTICE

1. A five-pointed star is inscribed in the circle *A B C D E*, Fig. 12. The diameter of the circle is 4 feet 6 inches. What is the distance between consecutive points of the star measured on a straight line? Ans. 2 ft. $7\frac{13}{16}$ in., nearly

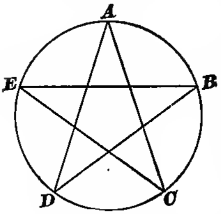


Fig. 12

2. Each side of an octagonal room is 12 feet 3 inches. Find the number of square feet of flooring required for the room, making no allowance for waste. Ans. 724.56 sq. ft.

3. What is the area of the end of a hexagonal rod, if the distance between parallel sides of the rod is 2 inches? Ans. 3.46 sq. in.

4. In Fig. 13, *A B C D* represents the end section of a piece of timber 6 inches square. (*a*) What will be the side of a regular octagon that may be formed from the stick, if the corners are cut off as shown? (*b*) What is the distance *B E*?

$$\text{Ans.}\begin{cases}(a)\ 2\frac{1}{2}\text{ in.}\\(b)\ 1\frac{3}{4}\text{ in.}\end{cases}$$

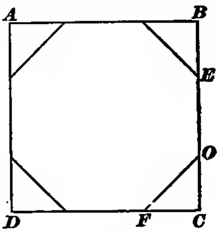


Fig. 13

CIRCLE

23. The ratio of the circumference of a circle to its diameter is usually denoted by the Greek letter π (pronounced *pie*). The approximate value of the ratio, correct to four decimal places, is 3.1416; hence, approximately, $\pi=3.1416$. For off-hand calculations, the ratio is frequently taken as $3\frac{1}{7}$; that is, the circumference is $3\frac{1}{7}$ times the diameter.

24. The following rules are used to find the circumference, diameter, and radius of a circle:

Rule I.—*To find the circumference of a circle, multiply the diameter by 3.1416; or, multiply the radius by 2×3.1416.*

Rule II.—*To find the diameter of a circle, divide the circumference by 3.1416; or, divide the circumference by 2×3.1416 to find the radius.*

Let c = circumference of circle·
d = diameter of circle;
r = radius of circle;
π = 3.1416

Then, the preceding rules may be expressed by the formulas

$$c = \pi d = 2\pi r \qquad (1)$$

$$d = \frac{c}{\pi} \qquad (2)$$

$$r = \frac{c}{2\pi} \qquad (3)$$

Example.—A wheelwright wishes to cut a length of tire iron long enough to go around a 4½-foot wagon wheel. How long a piece should be cut, if it is necessary to allow 1½ inches for welding?

Solution.—Here $d = 4\frac{1}{2}$ ft.; so, apply formula **1**, thus:

$$c = \pi\, d = 3.1416 \times 4\tfrac{1}{2} = 14.14 \text{ ft.} = 14 \text{ ft. } 1\tfrac{3}{4} \text{ in., nearly}$$

Adding the 1½ in., the length required is 14 ft. 3¼ in. Ans.

25. The length of an arc of a circle may be found by the following rule:

Rule.—*To find the length of an arc of a circle, multiply the number of degrees in the arc by the radius, and divide by 57.3, or by 57.296 if greater precision is required.*

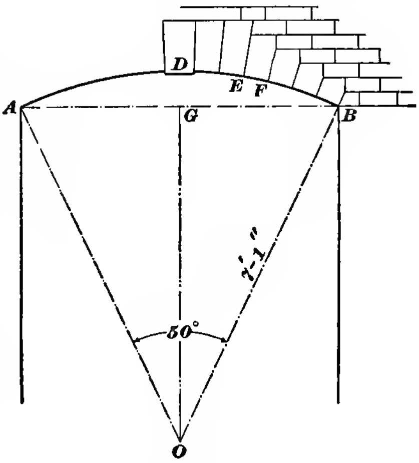


Fig. 14

Let l = length of arc;
r = radius of arc;
n = number of degrees in arc.

Then,

$$l = \frac{r\,n}{57.3}$$

If the angle contains degrees, minutes, and seconds, reduce them to degrees and decimals of a degree before substituting the value of the angle in the formula; for example,

$$37^\circ\, 30'\, 15'' = 37^\circ + \tfrac{30}{60}{}^\circ + \tfrac{15}{3600}{}^\circ$$
$$= 37^\circ + .5^\circ + .004^\circ = 37.504^\circ$$

Example.—In Fig. 14 is shown a part of a stone arch, the outline of the under surface of which is an arc $A\ D\ B$ of a circle having a radius of 7 feet 1 inch, or 85 inches. The angle $A\ O\ B$ is 50°. If there are thirteen stones in the arch, what will be the width, as $E\ F$, of each stone, measured along the arc?

Solution.—Here $l = A\ D\ B$, the length of the arc; $r = 85$ in., and $n = 50°$. Apply the formula, and

$$l = \frac{r\,n}{57.3} = \frac{85 \times 50}{57.3} = 74.17 \text{ in.}$$

Divide by the number of stones, and the width of each is $74.17 \div 13 = 5.71$ in. $= 5\frac{11}{16}$ in., nearly. Ans.

26. When only the chord $A\ B$, Fig. 15, of an arc and the height, or rise, $C\ D$ of the segment are known, the following approximate method of finding the length of arc gives good results. $A\ C$, the chord of half the arc, has the value

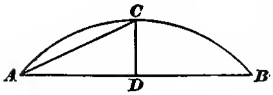


Fig. 15

$$A\ C = \sqrt{\overline{A\ D}^2 + \overline{C\ D}^2} = \sqrt{\left(\frac{A\ B}{2}\right)^2 + \overline{C\ D}^2}$$

Then, to find the length of the arc use the following rule:

Rule.—*From eight times the chord of one-half the arc, subtract the chord of the whole arc and divide the remainder by 3.*

That is, $$\text{arc } A\ C\ B = \frac{(8 \times A\ C) - A\ B}{3}$$

Let
c = chord of whole arc;
h = height of segment;
l = length of arc.

Then, $$A\ C = \sqrt{\frac{c^2}{4} + h^2} = \frac{1}{2}\sqrt{c^2 + 4h^2}$$

and $$l = \frac{4\sqrt{c^2 + 4h^2} - c}{3}$$

Either the rule or the formula may be used, whichever is the more convenient.

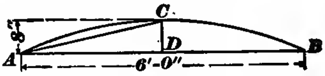


Fig. 16

This method gives the length of an arc less than one-sixth of the circumference correct to four figures, and it gives the length of an arc less than one-third of the circumference correct to three figures.

EXAMPLE.—Find the length of the arc $A\ C\ B$, Fig. 16.

SOLUTION.—$A\ B=6$ ft. $=72$ in. $A\ D$, which is one half of $A\ B$ equals $\frac{1}{2}\times72=36$ in.; and $D\ C=8$ in.

$$A\ C=\sqrt{\overline{A\ D}^2+\overline{D\ C}^2}=\sqrt{36^2+8^2}=36.88 \text{ in.}$$

Hence, the length of the arc $A\ C\ B$ is

$$\frac{(8\times A\ C)-A\ B}{3}=\frac{(8\times36.88)-72}{3}=74.35 \text{ in., or 6 ft. } 2\tfrac{3}{8} \text{ in., nearly. Ans.}$$

27. When the results that may be obtained by the method given in the preceding article are not considered sufficiently accurate, the length of one-half the arc may be found in a similar manner and this multiplied by 2. The following example will fully illustrate the method of procedure:

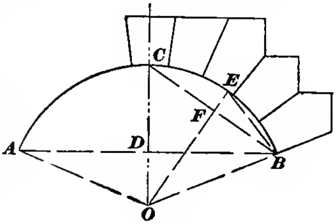


FIG. 17

EXAMPLE.—The arch in Fig. 17 has a span $A\ B$ of 60 inches and a rise $C\ D$ of 25 inches. What is the length of the arc $A\ C\ B$?

SOLUTION.—Let O represent the center of the arch, and let F be the middle point of the chord $C\ B$.

$$\overline{C\ B}^2=\overline{C\ D}^2+\overline{D\ B}^2=25^2+\left(\tfrac{60}{2}\right)^2=1{,}525$$

$$C\ B=\sqrt{1{,}525}=39.051 \text{ in.}$$

$$C\ F \text{ or } F\ B=C\ B\div2=39.051\div2=19.526 \text{ in.}$$

The radius, according to a principle explained in a preceding Section is

$$C\ O=\frac{\overline{C\ B}^2}{2\ C\ D}=\frac{1{,}525}{2\times25}=30.5 \text{ in.}$$

In the right triangle $C\ F\ O$,

$$O\ F=\sqrt{\overline{O\ C}^2-\overline{C\ F}^2}=\sqrt{30.5^2-19.526^2}=23.431 \text{ in.}$$

$$F\ E=O\ E-O\ F=30.5-23.431=7.069 \text{ in.}$$

In the right triangle $E\ F\ B$,

$$E\ B=\sqrt{\overline{E\ F}^2+\overline{F\ B}^2}-\sqrt{7.069^2+19.526^2}=20.766 \text{ in.}$$

According to the rule of Art. **26**,

$$\text{arc } C\ E\ B=\frac{8\ E\ B-C\ B}{3}=\frac{8\times20.766-39.051}{3}=42.359 \text{ in.}$$

The whole arc $A\ C\ B$ is therefore

$$2\times42.359=84.72 \text{ in., or 7 ft. } \tfrac{3}{4} \text{ in. Ans.}$$

If the rule of Art. **26**, is applied directly,

arc $A\,C\,B=\dfrac{(8\times C\,B)-A\,B}{3}=\dfrac{8\times 39.051-60}{3}=84.14$ in., or 7 ft. $\frac{1}{8}$ in. approximately. Ans.

A difference of results, as in this case, is to be expected when answers are obtained by different methods.

28. If the radius of an arc and the length of the chord are given, the height of the segment may be found. In Fig. 17, for example, suppose that the chord $A\,B$ and the radius $O\,A$ are known, and that the height $C\,D$ is to be found. As $A\,C\,B$ is an arc of a circle, $O\,C=O\,A$. But, $O\,C=C\,D+D\,O$; or, $C\,D=O\,C-D\,O$. Now, $D\,O$ is one side of a right triangle $A\,D\,O$, the hypotenuse being $O\,A$ and the other side being $A\,D=\frac{1}{2}A\,B$. Therefore,

$$\overline{D\,O}^2=\overline{O\,A}^2-\overline{A\,D}^2$$

or,

$$\overline{D\,O}^2=\overline{O\,A}^2-(\tfrac{1}{2}\overline{A\,B})^2$$

from which

$$D\,O=\sqrt{\overline{O\,A}^2-\tfrac{1}{4}\overline{A\,B}^2}$$

Then,

$$C\,D=O\,C-\sqrt{\overline{O\,A}^2-\tfrac{1}{4}\overline{A\,B}^2}$$

or,

$$C\,D=O\,A-\sqrt{\overline{O\,A}^2-\tfrac{1}{4}\overline{A\,B}^2} \qquad (1)$$

If the radius $O\,A$ and the height $C\,D$ are known, the length of the chord $A\,B$ may be found by the formula

$$A\,B=2\sqrt{\overline{O\,A}^2-(O\,A-C\,D)^2} \qquad (2)$$

29. The area of a sector of a circle may be found by the following rule:

Rule.—*To find the area of a sector of a circle, divide the number of degrees in the arc of the sector by 360. Multiply the result by the area of the circle of which the sector is a part.*

Let
a = area of sector;
n = number of degrees in arc;
A = area of circle;
r = radius of circle.

Then,

$$a=\frac{n\,A}{360}=.0087267\,n\,r^2$$

Example.—A circular window 4 feet in diameter is divided by radial ribs into twelve equal sections. What is the area of each space?

Solution.—Here $n=\frac{360°}{12}=30°$; so apply the formula, and

$$a=\frac{n\,A}{360}=\frac{30\times.7854\times4^2}{360}=1.05 \text{ sq. ft.}\quad\text{Ans.}$$

Or, $a=.0087267\,n\,r^2=.0087267\times30\times4=1.05$ sq. ft. Ans.

30. The area may also be found by the following rule:

Rule.—*To find the area of a sector, multiply one-half of the length of the arc by the radius.*

Let a = area of sector;
l = length of arc;
r = radius of arc.

Then, $a=\frac{1}{2}\,l\,r$

Example.—In the sector $O\,A\,C\,B$, Fig. 18, the radius $O\,A$ ($=O\,C$) of the arc is 6 inches, and the length of the chord $A\,B$ is 7 inches. What is the area of the sector $O\,A\,C\,B$?

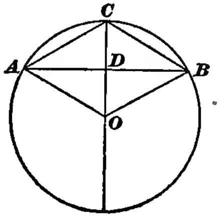


Fig. 18

Solution.—In order to find the area, it will be necessary first to find the length of the arc, by applying the rule given in Art. **26**; but before applying this rule, the height $C\,D$ of the segment will have to be found. Since $A\,D=\frac{1}{2}\,A\,B=\frac{1}{2}\times7=3.5$,

$$O\,D=\sqrt{\overline{O\,A}^2-\overline{A\,D}^2}=\sqrt{6^2-3.5^2}=4.87 \text{ in.}$$

Then, $C\,D=O\,C-O\,D=6-4.87=1.13$ in.

$$C\,B=\sqrt{\overline{C\,D}^2+\overline{D\,B}^2}=\sqrt{1.13^2+3.5^2}=3.68 \text{ in.}$$

and $$\text{arc } A\,C\,B=\frac{8\times C\,B-A\,B}{3}=\frac{8\times3.68-7}{3}=7.48 \text{ in.}$$

Now apply the formula given in this article, and

$$a=\tfrac{1}{2}\,l\,r=\tfrac{1}{2}\times7.48\times6=22.44 \text{ sq. in.}\quad\text{Ans.}$$

31. The area of a segment of a circle may be found, approximately, as follows:

Rule.—*To two-thirds of the product of the height of the segment and the chord add the quotient obtained by dividing the cube of the height of the segment by twice the chord.*

Let A = area of segment;

c = chord;

h = height of segment.

Then,
$$A = \tfrac{2}{3}ch + \frac{h^3}{2c}$$

This rule will give results correct to three figures when the height of segment does not exceed the length of one-fourth of the chord, and the error will be less than 1 per cent. in finding the area of a semicircle. The rule is therefore sufficiently accurate for most ordinary calculations, as in estimating quantities and costs.

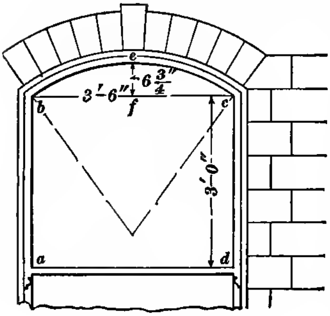


Fig. 19

Example.—What is the area of the upper pane of glass *a b e c d* in the window shown in Fig. 19?

Solution.—The glass may be divided into a rectangle *a b c d* 3 ft.×3 ft. 6 in. and a segment *b e c* of a circle, the length of its chord *b c* being 3 ft. 6 in. and the height *e f* of segment 6.75 in. But, 3 ft. = 36 in., and 3 ft. 6 in. = 42 in. The area of the rectangle is, therefore, 42×36 = 1,512 sq. in. Referring to the segment, c = 3 ft. 6 in. = 42 in., and h = 6.75 in. Substitute in the formula, and

$$A = \tfrac{2}{3}\times 42\times 6.75 + \frac{6.75^3}{2\times 42}$$
$$= 189 + \frac{307.55}{84} = 189 + 3.66$$
$$= 192.66 \text{ sq. in.}$$

The entire area of the glass is

1,512+192.66 = 1,704.66 sq. in. Ans.

32. The exact area of a segment of a circle may be found by the following rule:

Rule.—*To find the area of a segment of a circle, find the area of the sector of which the segment is a part, and from this area subtract the area of the triangle formed by drawing radii to the extremities of the chord of the segment. The result is the area of the segment.*

EXAMPLE.—What is the area of the segment *A C B*, Fig. 18?

SOLUTION.—The area of the segment is equal to the difference between the areas of the sector *O A C B* and the triangle *O A B*. The area of *O A C B* has been found, in the solution to the example in Art. **30,** to be 22.44 sq. in. Area of triangle *O A B* is

$$\tfrac{1}{2}\times O\,D\times A\,B=\tfrac{1}{2}\times 4.87\times 7=17.05 \text{ sq. in.}$$

Area of segment *A C B* is, therefore,

$$22.44-17.05=5.39 \text{ sq. in. Ans.}$$

33. The following rule is employed to find the area of a circle:

Rule.—*To find the area of a circle, square the diameter and multiply by .7854; or, square the radius and multiply by 3.1416.*

Let A = area of circle;
d = diameter of circle;
r = radius of circle.

Then,

$$A=\tfrac{1}{4}\pi d^2=.7854d^2 \qquad (1)$$

$$A=\pi r^2=3.1416r^2 \qquad (2)$$

EXAMPLE 1.—What is the area of a circle whose radius is 14 inches?

SOLUTION.—Apply formula **2,** and

$$A=3.1416\times 14^2=3.1416\times 196=615.75 \text{ sq. in. Ans.}$$

EXAMPLE 2.—The contract for a brick warehouse provides that all openings over 4 feet wide shall be deducted. What must be deducted for a semicircular arch 4 feet 8 inches in diameter?

SOLUTION.—Here d=4 ft. 8 in. $=4\tfrac{2}{3}$ ft. Apply formula **1,** and

$$A=.7854d^2=.7854\times(4\tfrac{2}{3})^2=.7854\times 21.78=17.11 \text{ sq. ft.}$$

The area of the half circle is

$$17.11\div 2=8.56 \text{ sq. ft., or practically } 8\tfrac{1}{2} \text{ sq. ft. Ans.}$$

34. When the area of a circle is given, the diameter may be found by applying the following rule:

Rule.—*To find the diameter of a circle, the area being given, divide the area by .7854 and extract the square root of the quotient.*

$$d=\sqrt{\frac{A}{.7854}}=\sqrt{\frac{4A}{\pi}}$$

EXAMPLE.—To supply a certain quantity of water, it is necessary to have a pipe with an area of 28 square inches. What must be the diameter of the pipe?

SOLUTION.—Apply the formula just given, and

$$d=\sqrt{\frac{A}{.7854}}=\sqrt{\frac{28}{.7854}}=\sqrt{35.65}=5.97 \text{ in.}$$

As this is almost 6 in., a pipe of that diameter would be chosen. Ans.

35. The area of a flat circular ring, Fig. 20, may be found as follows:

Rule.—*To find the area of a flat circular ring, subtract the area of the smaller circle from that of the larger.*

Let A = area of ring;
d = outside diameter;
d_1 = inside diameter.

Then, $A=.7854d^2-.7854d_1^2=.7854\ (d^2-d_1^2)$

EXAMPLE.—What is the sectional area of a brick stack whose external and internal diameters are 6 feet 6 inches and 4 feet, respectively?

SOLUTION.—Here $d=6.5$ ft., and $d_1=4$ ft.; so, apply the formula and,
$A=.7854\times(6.5^2-4^2)=.7854\times26.25=20.62$ sq. ft. Ans.

If one diameter and the area of the ring are known, the other diameter may be found as follows: Compute the area of the circle whose diameter is given and add to or subtract from this result the area of the ring. The sum or difference thus found will be the area of the circle whose diameter is required.

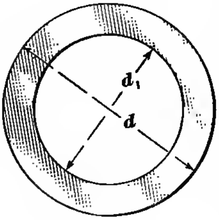


FIG. 20

If the outside diameter d and the width of the ring are given, and the area is to be found, multiply the width by 2 and subtract the product from the value of d. The remainder will be the value of d_1. Then, knowing d and d_1, the area may be found by the rule just given.

ELLIPSE

36. An **ellipse** is a plane figure bounded by a curved line, to any point of which the sum of the distances from two fixed points within, called the *foci*, is equal to the sum of the distances from the foci to any other point on the curve.

The curve bounding the ellipse is called the *circumference*, or *perimeter*, of the ellipse.

In Fig. 21, let A and B be the foci, and let C and D be any two points on the perimeter. Then, according to the definition just stated,

$$AC+CB=AD+DB$$

Each of these sums is also equal to the major axis EF. The long diameter EF is called the *major axis;* the short diameter GD, the *minor axis.* The foci may be located from D or G as a center, and radius $DA=DB=\frac{1}{2}EF$.

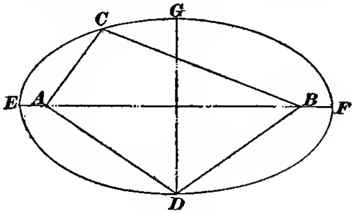


FIG. 21

37. There is no simple and exact method of finding the perimeter of an ellipse. The following formula gives values very nearly exact:

Let C = perimeter;
a = half the major axis;
b = half the minor axis;
$D=\frac{a-b}{a+b}$.

Then, $$C=\pi(a+b)\frac{64-3D^4}{64-16D^2}$$

EXAMPLE.—What is the perimeter of an ellipse whose axes are 12 inches and 8 inches long?

SOLUTION.—In this example, $a=6$ and $b=4$; hence, $D=\frac{6-4}{6+4}=\frac{2}{10}=.2$.

Then, $$C=\pi(6+4)\frac{64-3(.2)^4}{64-16(.2)^2}$$

The only difficulty in simplifying this expression will be in reducing the fraction $\frac{64-3(.2)^4}{64-16(.2)^2}$ to its simplest form.

The numerator is simplified by raising .2 to the fourth power and subtracting three times the power from 64. Thus,

$$.2^4=.2\times.2\times.2\times.2=.0016;\ 3\times.0016=.0048$$

Then, $$64-3(.2)^4=64-.0048=63.9952.$$

The denominator is simplified by multiplying the second power of .2 by 16 and subtracting the product from 64. Thus,

$$.2^2=.2\times.2=.04;\ 16\times.04=.64;\ 64-.64=63.36$$

The fraction therefore equals $\frac{63.9952}{63.36} = 1.010$. Consequently,

$C = 3.1416 \times 10 \times 1.010 = 31.73$ in., or 2 ft., $7\frac{3}{4}$ in., nearly. Ans.

38. The following rule gives the method of finding the area of an ellipse:

Rule.—*To find the area of an ellipse, multiply the product of its two diameters by .7854.*

Let
A = area of ellipse;
D = long diameter;
d = short diameter.

Then,
$$A = \frac{1}{4}\pi dD = .7854dD$$

Example.—What is the area of the elliptic top of a table whose long and short diameters are 4 and 3 feet, respectively?

Solution.—Here $D = 4$ ft. and $d = 3$ ft.; so, apply the formula, and

$A = .7854\ D\ d = .7854 \times 4 \times 3 = 9.42$ sq. ft. Ans.

EXAMPLES FOR PRACTICE

1. Find the area of a square whose side is 5 feet 9 inches.
Ans. 33.06 sq. ft.

2. Find the area of a rhombus whose side is 12 feet 6 inches, and whose height is 9 feet 3 inches.
Ans. 115.62 sq. ft.

3. How many square feet are there in a board 12 feet long, 18 inches wide at one end, and 12 inches wide at the other end?
Ans. 15 sq.ft.

4. Find the distance around the outside of a waterwheel whose outside diameter is 22 feet 8 inches.
Ans. 71 ft. $2\frac{1}{2}$ in.

5. The wheel of a carriage is observed to turn 375 times in going from a certain place to another. If the diameter of the wheel is 3 feet 6 inches, what is the distance between the two places?
Ans. 4,123 ft. $4\frac{3}{4}$ in., approximately

6. A circular column measures $45\frac{1}{2}$ inches around the outside. What is its diameter?
Ans. $14\frac{1}{2}$ in., nearly

7. A belt covers an arc of 50° on a pulley whose diameter is 5 feet. What length of belt is in contact with the pulley?
Ans. 2 ft. $2\frac{3}{16}$ in., nearly

8. Find the area of a triangle whose three sides are 13, 14, and 15 feet.
Ans. 84 sq. ft.

9. Find the area of a right triangle whose hypotenuse is 50 feet and one of whose sides is 40 feet. Ans. 600 sq. ft.

10. The parallel sides of a trapezoid are 321 feet 6 inches, and 214 feet 3 inches, and the perpendicular distance between them is 171 feet $1\frac{1}{2}$ inches. What is the area of the trapezoid? Ans. 45,840 sq. ft.

11. One side of a room is 16 feet long. If the floor contains 240 square feet, what is the width of the room? Ans. 15 ft.

12. The cable of a suspension bridge measures 40 inches in circumference. Find: (*a*) the diameter of the cable; (*b*) the area of the cross-section.

Ans. (*a*) $12\frac{3}{4}$ in., nearly
(*b*) 127.3 sq. in.

13. In Fig. 15, if $AB = 40$ inches and $CD = 7\frac{1}{2}$ inches, find (*a*) the length of the arc ACB and (*b*) the radius of the arc.

Ans. (*a*) 3 ft. $7\frac{5}{8}$ in., approximately
(*b*) 2 ft. $6\frac{7}{16}$ in., nearly

14. (*a*) What is the perimeter of an ellipse whose axes are 15 inches and 9 inches? (*b*) What is the area?

Ans. (*a*) 3 ft. $2\frac{1}{4}$ in., approximately
(*b*) 106.03 sq. in.

MENSURATION OF SOLIDS

DEFINITIONS

39. A **solid,** or body, has three dimensions: length, breadth, and thickness. The sides that enclose it are called the **faces,** and their intersections are called **edges.**

40. The **entire surface** of a solid is the area of the whole outside of the solid, including the ends.

The **convex,** or **lateral, surface** of a solid is the same as the entire surface, except that the areas of the ends are not included.

41. The **volume** of a solid is the space included between its bounding surfaces, and is expressed by the number of times it will contain another volume, called the unit of volume. Instead of the word *volume,* the expression **cubic contents** is frequently used.

PRISM AND CYLINDER

42. A **prism** is a solid whose ends are equal parallel polygons and whose sides are parallelograms. Prisms take their names from their bases. Thus, a triangular prism is one whose bases are triangles; a pentagonal prism is one whose bases are pentagons, etc.

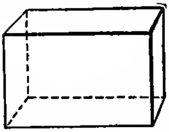


FIG. 22

43. A **parallelopiped,** as shown in Fig. 22, is a prism whose bases (ends) are parallelograms.

44. A **cube,** as shown in Fig. 23, is a parallelopiped whose faces and ends are squares.

45. The cube whose edges are equal to the unit of length is taken as the unit of volume when finding the volume of a solid. Thus, if the unit of length is 1 inch, the unit of volume will be the cube whose edges measure 1 inch, or 1 *cubic inch;* and the number of cubic inches the solid contains will be its volume. If the unit of length is 1 foot, the unit of volume will be 1 *cubic foot,* etc. Cubic inch, cubic foot, and cubic yard are abbreviated to cu. in., cu. ft., and cu. yd., respectively.

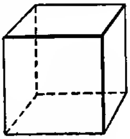


FIG. 23

46. A **cylinder,** shown in Fig. 24, is a solid whose ends are parallel and equal *curved* figures, and whose cross-section is uniform throughout its length. The *axis* of a cylinder is a straight line joining the centers of the ends, as shown. A *circular cylinder* is one any section of which, perpendicular to the axis, is a circle. Unless otherwise expressed the word *cylinder* always means a *circular cylinder.*

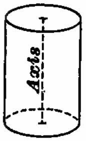


FIG. 24

47. A *right prism,* or *right cylinder,* is one whose axis is perpendicular to its base.

48. The *altitude* of a prism or cylinder is the perpendicular distance between its two ends.

49. The area of the convex surface of any right prism or right cylinder may be found according to the following rule:

Rule.—*To find the area of the convex surface of any right prism or right cylinder, multiply the perimeter of the base by the altitude.*

Let S = convex surface;
p = perimeter of base;
h = altitude.
Then, $S = p\,h$

To find the entire area, add the areas of the two ends to the convex area.

Example 1.—A circular iron chimney, 7 feet in diameter and 85 feet high, is to be covered outside with a preservative paint. What will it cost to paint the chimney at 20 cents per square yard?

Solution.—The perimeter p of the base is $\pi\,d = 21.99$ ft., and $h = 85$ ft. The surface of the chimney is $21.99 \times 85 = 1{,}869.2$ sq. ft., or 207.7 sq. yd. The cost of painting at 20 cents per sq. yd. is therefore

$207.7 \times \$.20 = \$41.54$. Ans.

Example 2.—How many square feet of zinc will be required to line a refrigerator having interior dimensions of 4 ft. × 6 ft. × 8 ft. high?

Solution.—The area of the sides is

$(4 \times 2 + 6 \times 2) \times 8 = 160$ sq. ft.

Adding for floor and ceiling

$(4 \times 6) \times 2 = 48$ sq. ft.; the total is 208 sq. ft. Ans.

Example 3.—What will be the cost, at 35 cents per square yard, of plastering the walls and ceiling of an octagonal room, having sides 5 feet long and 11 feet high, the distance between the parallel sides being 12 feet?

Solution.—The area of the sides is $8\ (5 \times 11) = 440$ sq. ft.; the area of the ceiling is one-half the perimeter times one-half the distance between the parallel sides, or $\frac{8 \times 5 \times 6}{2} = 120$ sq. ft.; the total is 560 sq. ft., or 62.22 sq. yd. At 35 ct. per sq. yd., the cost is \$21.78. Ans.

50. The volume of a rectangular solid may be found as follows:

Rule.—*To find the volume of a rectangular solid, multiply together the length, breadth, and height.*

Let V = volume;
l = length;
b = breadth;
h = height.
Then, $V = l\,b\,h$

Example.—Find the volume of the rectangular block shown in Fig. 25.

Solution.—The length is 4 in., the breadth is 3 in., and the height is 6 in. The volume therefore is

$$V = 4\times 3\times 6 = 72 \text{ cu. in.} \quad \text{Ans.}$$

The block may be divided into six pieces, each 4 in. long, 3 in. wide, and 1 in. thick. Each of these pieces may be cut up into twelve 1-in. cubes. There will, therefore, be $6\times 12=72$ one-inch cubes, or 72 cu. in. in the entire block.

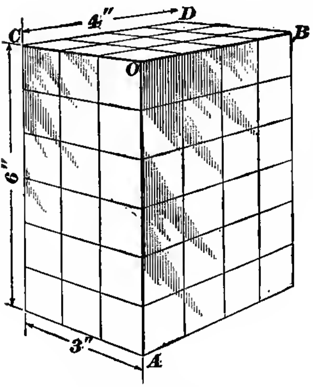


Fig. 25

51. The volume of a right prism, or cylinder, may be found by the following rule:

Rule.—*To find the volume of a right prism, or cylinder, multiply the area of the base by the altitude.*

Let V = volume;
a = area of base;
h = altitude.

Then, $V = a\,h$

If the given prism is a cube, the three dimensions are all equal, and the volume is equal to the cube of one of the edges.

If the volume and area of the base are given, the altitude is $\frac{V}{a}$. If a cylinder is hollow, the area of the base is equal to the area of a flat ring like that shown in Fig. 20.

Example 1.—If brickwork averages 21 bricks per cubic foot, how many bricks will there be in a pier 18 inches square and 6 feet high?

Solution.—The sectional area or a is $1.5\times 1.5=2.25$ sq. ft.; $h=6$ ft.; hence,

$$V = a\,h = 2.25\times 6 = 13.5 \text{ cu. ft.}$$

At 21 bricks per cubic foot, the number of bricks in the pier is

$$13.5\times 21 = 283.5. \quad \text{Ans.}$$

Example 2.—If cast iron weighs .26 pound per cubic inch, what length of sash weight will be necessary to balance a window weighing 8 pounds, the diameter of the cylindrical weight being 1$\frac{1}{2}$ inches?

SOLUTION.—As there are two weights, the weight of each is 4 lb. The number of cubic inches required, or V, is $4 \div .26 = 15.38$. The area a of a $1\frac{1}{2}$-in. circle is 1.77 sq. in.; hence, h, the length, is

$$\frac{V}{a} = \frac{15.38}{1.77} = 8.69 \text{ in., or } 8\tfrac{11}{16} \text{ in.} \quad \text{Ans.}$$

BOARD MEASURE

52. In measuring sawed lumber, the unit of measure is the **board foot,** and it is equal to the contents of a board 1 foot square and 1 inch thick. A board foot is, therefore, equal to one-twelfth of a cubic foot. Boards less than 1 inch thick are usually reckoned as though the thickness were 1 inch.

Rule I.—*To find the number of board feet in a piece of lumber, multiply together the length, in feet, the width, in feet, and the thickness, in inches.* Or,

Rule II.—*Multiply together the length, in feet, the width, in inches, and the thickness, in inches, and divide the product by 12.*

EXAMPLE 1.—How many board feet are there in a plank 10 feet 6 inches long, 15 inches wide, and 3 inches thick?

SOLUTION.—Length $= 10$ ft. 6 in. $= 10\frac{6}{12}$ ft. $= 10\frac{1}{2}$ ft. $= 10.5$ ft., width $= \frac{15}{12}$ ft. $= 1.25$ ft. The number of feet equals

$$10.5 \times 1.25 \times 3 = 39.375, \text{ or } 39.4$$

The result is, therefore, 39.4 ft. B. M. (board measure). Ans.

EXAMPLE 2.—Find the number of board feet in twenty pieces of siding $\frac{1}{2}$ inch thick, $5\frac{1}{2}$ inches wide, and 10 feet 9 inches long.

SOLUTION.—Since the thickness is less than 1 in., the boards are considered to be 1 in. thick when finding the amount of material in them. The calculation can be more easily performed in this case by using the second rule. Length $= 10\frac{9}{12}$ ft. $= 10.75$ ft., width $= 5\frac{1}{2}$ in. $= 5.5$ in.

$$\frac{20 \times 10.75 \times 5.5 \times 1}{12} = \frac{1{,}182.5}{12} = 98.54 \text{ ft. B. M.} \quad \text{Ans.}$$

PYRAMID AND CONE

53. A **pyramid** is a solid whose base is a polygon and whose sides are triangles uniting at a common point, called the **vertex.** A square pyramid is shown in Fig. 26.

54. A **cone** Fig. 27, is a solid whose base is a circle and whose convex surface tapers uniformly to a point called the *vertex.*

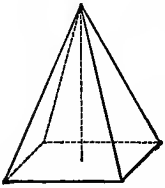


FIG. 26

55. A **right pyramid** or **cone** is one whose axis is perpendicular to the base.

56. The **altitude** of a pyramid or cone is the perpendicular distance from the vertex to the base.

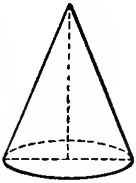


FIG. 27

57. The **slant height** of a *pyramid* is a line drawn from the vertex perpendicular to one of the sides of the base. It is the hypotenuse of a right triangle, one of whose sides is the height of the pyramid and the other is half the width of the base. The slant height of a *cone* is any straight line drawn from the vertex to the circumference of the base. It is the hypotenuse of a right triangle, one of whose sides is the height of the cone and the other is half the diameter of the base.

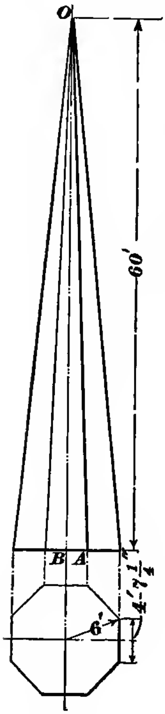


FIG. 28

58. The convex area of a right pyramid or cone may be found as follows:

Rule.—*To find the convex area of a right pyramid or cone multiply the perimeter of the base by one-half of the slant height.*

Let A = convex area;
p = perimeter of base;
s = slant height.

Then, $$A = \frac{ps}{2}$$

EXAMPLE.—A church steeple, in the form of an octagonal pyramid, as shown in Fig. 28, is 60 feet high. The outer radius of the base, or the radius of the circumscribed circle, is 6 feet, and the length of one of the sides of the base is 4 feet $7\frac{1}{4}$ inches. Find the convex surface.

Solution.—To find the slant height, the length OA along one edge must first be found. This is the hypotenuse of a right triangle of which the altitude is the height of the tower, or 60 ft., and the base is the radius, or 6 ft. Hence, $OA=\sqrt{60^2+6^2}=60.3$ ft. Now, in the triangle OAB, OA is 60.3 ft. and AB is half the length of one side of the octagonal base; but 4 ft. 7¼ in. = 4.6 ft., approximately, and so $AB=4.6\div2=2.3$ ft. The slant height OB is, therefore, $\sqrt{60.3^2-2.3^2}=60.3$ ft., nearly. The perimeter of the base is $4.6\times8=36.8$ ft. Apply the formula, and

$$A=\frac{ps}{2}=\frac{36.8\times60.3}{2}=1{,}109.5 \text{ sq. ft. Ans.}$$

59. The following rule states how to find the volume of a pyramid or cone:

Rule.—*To find the volume of a pyramid or cone, multiply the area of the base by one-third of the altitude.*

Let V = volume;
a = area of base;
h = altitude.

Then, $$V=\frac{ah}{3}$$

Example 1.—The granite capstone of a monument is a square pyramid having a base 4 feet square and an altitude of 6 feet. If granite weighs 170 pounds per cubic foot, what will be the freight charges on the piece at 20 cents per 100 pounds?

Solution.—The area a of the base is $4\times4=16$ sq. ft., and the altitude h is 6 ft. Apply the formula, and

$$V=\frac{ah}{3}=\frac{16\times6}{3}=32 \text{ cu. ft.}$$

At 170 lb. per cu. ft., the weight is $32\times170=5{,}440$ lb. $=54.4$ cwt. The freight is, therefore,

$$54.4\times\$.20=\$10.88. \text{ Ans.}$$

Example 2.—If, in the preceding example, the capstone were conical, having a base 4 feet in diameter and a height of 6 feet, how much less would it weigh than the pyramidal stone?

Solution.—The area of the base is $.7854\,d^2=12.57$ sq. ft. Apply the formula, and the volume is

$$\frac{12.57\times6}{3}=25.14 \text{ cu. ft.}$$

and the weight at 170 lb. per cu. ft. is 4,274 lb., nearly. As the pyramidal capstone weighs 5,440 lb., the difference in weight is

$$5{,}440-4{,}274=1{,}166 \text{ lb. Ans.}$$

FRUSTUM OF PYRAMID OR CONE

60. If a pyramid or a cone is cut by a plane parallel to the base, so as to form two parts, the lower part is called the **frustum** of the pyramid or cone. The lower part in Fig. 29 is a frustum of a pyramid, and the lower part in Fig. 30 is a frustum of a cone.

The upper end of the frustum of a pyramid or cone is called the *upper base*, and the lower end the *lower base*. The altitude of a frustum is the perpendicular distance between the bases.

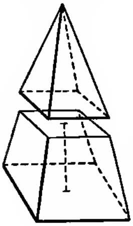


FIG. 29

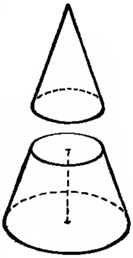


FIG. 30

61. The convex area of a frustum of a right pyramid or right cone is found as follows:

Rule.—*To find the convex area of a frustum of a right pyramid or right cone, multiply one-half the sum of the perimeters of the bases by the slant height.*

Let A = convex area;
P = perimeter of lower base;
p = perimeter of upper base;
s = slant height.

Then,

$$A = \frac{(P+p)s}{2}$$

To find the entire area, add to the convex area the areas of the two bases.

To find the slant height of a frustum of a right pyramid or right cone, take the difference between the radii of the inscribed circles of the two bases, or between the radii of the two bases. This difference is one side of a right triangle whose other side is the altitude of the frustum. The hypotenuse of this right triangle is the slant height.

EXAMPLE.—A square tower roof has the dimensions shown in Fig. 31. To find the slate required to cover the tower the convex area is required. What is this convex area?

Solution.—The tower has the form of a frustum of a pyramid, 6 ft. 6 in. square at the bottom and 3 ft. 6 in. square at the top, 6 ft. being the altitude. 6 ft. 6 in. $=6\frac{1}{2}$ ft. and 3ft. 6 in. $=3\frac{1}{2}$ ft. The perimeter of the lower base is $4\times6\frac{1}{2}=26$ ft., and that of the upper base is $4\times3\frac{1}{2}=14$ ft. The slant height *A B* of the frustum is the hypotenuse of the right triangle *A C B* whose height *A C* is equal to the altitude of the frustum or 6 ft., and whose base *B C* is equal to the difference between the radii of the circles inscribed in the upper and lower bases, or

$$\tfrac{1}{2}(6\tfrac{1}{2}-3\tfrac{1}{2})=1\tfrac{1}{2}\text{ ft.}$$

The slant height is, therefore,

$$\sqrt{(1\tfrac{1}{2})^2+6^2}=6.18\text{ ft.}$$

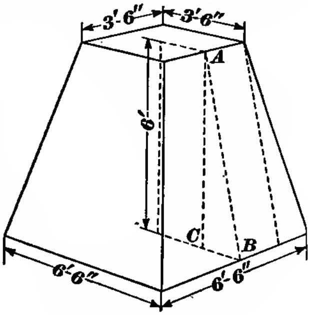


Fig. 31

Applying the formula,

$$A=\frac{(P+p)s}{2}=\frac{(26+14)\times6.18}{2}=123.6\text{ sq. ft.}\quad\text{Ans.}$$

62. The following rule gives a method of finding the volume of the frustum of a pyramid or cone:

Rule.—*To find the volume of the frustum of a pyramid or cone, add the areas of the upper base, the lower base, and the square root of the product of the areas of the two bases; multiply this sum by one-third of the altitude.*

Let A = area of lower base;

a = area of upper base;

h = altitude;

V = volume.

Then,

$$V=\frac{h}{3}(A+a+\sqrt{A\times a})$$

In this and other formulas of similar form, care should be taken to express the various dimensions in units of like denomination. For example, if the areas are expressed in square inches, the altitude must be in inches, and the result will be in cubic inches; if the areas are in square feet, the altitude must be in feet, and the result will be in cubic feet.

Example.—A marble monument is $2\frac{1}{2}$ feet square at the base, 1 foot square at the top, and 16 feet high. If marble weighs 160 pounds per cubic foot, what is the weight of the stone?

Solution.—The area of the lower base is $2\frac{1}{2}\times2\frac{1}{2}=6.25$ sq. ft.; that of the upper base is 1 sq. ft. Apply the formula, and

$$V=\frac{h}{3}(A+a+\sqrt{A\times a})=\frac{16}{3}(6.25+1+\sqrt{6.25\times1})=52 \text{ cu. ft.}$$

At 160 lb. per cu. ft., the weight is $52\times160=8{,}320$ lb. Ans.

63. When the bases of the frustum are square, let d and D represent the sides of the bases, respectively, and V the volume of the frustum; then,

$$V=\frac{h}{3}(d^2+d\,D+D^2)$$

When the bases are circular, let d and D represent the respective diameters; then,

$$V=\frac{h}{3}(d^2+d\,D+D^2)\times\frac{\pi}{4}$$

Example.—Find the volume of a pail having the form of a frustum of a cone, the upper and lower diameters being 10 and 8 inches, respectively, and the height of pail $9\frac{1}{2}$ inches.

Solution.—Substitute the given values in the formula, and

$$V=\frac{9.5}{3}(8^2+8\times10+10^2)\times.7854$$

$$=\frac{9.5}{3}\times244\times.7854=606.85 \text{ cu. in.} \quad \text{Ans.}$$

WEDGE

64. A **wedge,** Fig. 32, is a solid having plane surfaces, of which the base is a parallelogram, the ends are triangles, and the sides are quadrilaterals meeting in a line parallel to the sides of the base.

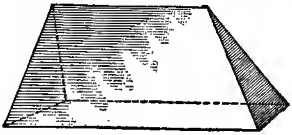


Fig. 32

65. The rule for finding the volume of a wedge is as follows:

Rule.—*To find the volume of a wedge, multiply together the width of the base, the perpendicular distance from the base to the edge, and the sum of the lengths of the three parallel edges; divide the product by 6.*

Let V = volume;

w = width of base;

h = perpendicular distance from base to edge;

s = sum of lengths of the three parallel edges.

Then, $$V=\frac{w\,h\,s}{6}$$

If the base is a rectangle, and the triangular ends are parallel, the wedge becomes a triangular prism, and the rule for prisms may be used.

Example.—Steel weighs .28 pound per cubic inch. How heavy is a steel wedge 8 inches long, and $1\frac{1}{2}$ in.×3 in. at the head?

Solution.—Here, w is $1\frac{1}{2}$ in., h is 8 in., s is $3+3+3=9$ in. Then,

$$V=\frac{1.5\times 8\times 9}{6}=18 \text{ cu. in.}$$

Or, as this wedge is a prism, the volume = area of end × length of edge; area of triangle is

$$\frac{1.5\times 8}{2}=6 \text{ sq. in.}$$

Multiply this by the length of the edge, 3 in., and the volume is 18 cu. in. The weight at .28 lb. per cu. in. is

$$.28\times 18=5.04 \text{ lb.} \quad \text{Ans.}$$

SPHERE

66. A **sphere,** Fig. 33, is a solid bounded by a uniformly curved surface, every point of which is equally distant from a point within called the center. The word *ball* is commonly used instead of *sphere.*

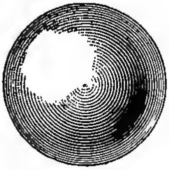


Fig. 33

67. The following rule states the method of finding the area of the surface of a sphere:

Rule.—*To find the area of the surface of a sphere, multiply the square of the diameter by 3.1416.*

Let S = surface;

d = diameter of sphere.

Then, $S=\pi d^2=3.1416d^2$

Example.—A ball on a flagstaff is 10 inches in diameter and is to be gilded, but 20 square inches is to be deducted for space covered by attachment to the pole. How many books of gold leaf, each containing 25 leaves $3\frac{3}{8}$ inches square, will be required for gilding it?

Solution.—Apply the formula. $S=\pi d^2=3.1416\times 10\times 10=314.16$ sq. in. Deducting 20 sq. in., the net surface is 294.16 sq. in. Each gold leaf has an area of $3\frac{3}{8}$ in. $\times 3\frac{3}{8}$ in., or 11.4 sq. in., nearly; hence, for 294.16 sq. in., there will be needed $294.16\div 11.4=25.8$ leaves, or 1 book and 1 leaf. Ans.

68. The volume of a sphere may be found when the diameter is known by applying the following rule:

Rule.—*To find the volume of a sphere, multiply the cube of the diameter by .5236.*

Let V = volume;
d = diameter.

Then, $$V=\frac{\pi}{6}d^3=.5236d^3$$

Since $\frac{\pi d^3}{6}=\frac{1}{6}\times\pi d^2\times d$, the volume of a sphere is equal to one-sixth of the surface multiplied by the diameter.

Example.—What is the weight of a cast-iron ball 6 inches in diameter, if the metal weighs .26 pounds per cubic inch?

Solution.—Apply the formula, and

$$V=.5236\,d^3=.5236\times 216=113.1 \text{ cu. in.}$$

The weight is therefore $113.1\times .26=29.41$ lb. Ans.

69. The volume of a spherical shell is equal to the difference in volume between two spheres having the outer and inner diameters of the shell.

70. The diameter of a sphere of known volume may be found by the following rule:

Rule.—*To find the diameter of a sphere of known volume, divide the volume by .5236 and extract the cube root of the quotient.*

$$d=\sqrt[3]{\frac{V}{.5236}}$$

Example.—A cast-iron ball weighing 52 pounds is required for a certain purpose. If cast iron weighs .26 pounds per cubic inch, what will be the diameter of the ball?

Solution.—The volume of the ball will be $52 \div .26 = 200$ cu. in. Then, by the formula,

$$d = \sqrt[3]{\frac{V}{.5236}} = \sqrt[3]{\frac{200}{.5236}} = \sqrt[3]{382} = 7.25 \text{ in.} = 7\tfrac{1}{4} \text{ in.} \quad \text{Ans.}$$

EXAMPLES FOR PRACTICE

1. A right cylinder is 26 inches in diameter and 32 inches high. Find its convex surface. Ans. 18 sq. ft., approximately

2. On a piece of level ground a cellar 24 feet wide, 36 feet long, and 7 feet deep is dug. How many cubic yards of earth are removed? Ans. 224 cu. yd.

3. A steel shaft is 4 inches in diameter and 10 feet long. What is its weight, if steel weighs .283 pound per cubic inch? Ans. 427 lb., nearly

4. Find the number of board feet in a timber 16 feet long, 12 inches wide, and 10 inches thick. Ans. 160 ft. B. M.

5. A conical tower 8 feet in diameter at the base and 12 feet high is to be painted. Find the area of convex surface. Ans. 159 sq. ft., nearly

6. A block of marble has the form of a pyramid whose base is 2 feet 6 inches square and whose height is 6 feet. If marble weighs 160 pounds per cubic foot, what is the weight of the block? Ans. 1 ton

7. A tank having the shape of a frustum of a cone is 8 feet high. The inside diameters at top and bottom are 5 feet and 6 feet, respectively. (*a*) How many gallons will the tank hold? (*b*) What is the area of the inside convex surface?

Ans. { (*a*) 1,426 gal., nearly
(*b*) 138.5 sq. ft.

8. A spherical balloon is 20 feet in diameter. (*a*) How many cubic feet of gas does it contain? (*b*) How many square feet of surface has it?

Ans. { (*a*) 4,189 cu. ft.
(*b*) 1,257 sq. ft.

SYMMETRICAL AND SIMILAR FIGURES

71. An **axis of symmetry** is any line so drawn that, if the part of the figure on one side of the line is folded over on this line, it will coincide exactly with the other part, point for point and line for line. Thus, in Fig. 34, if the upper semicircle is folded over on the diameter *C D*, it will coincide exactly with the lower semicircle; also, if the part on the right of the diameter *A B* is folded over on *A B*, it will coincide exactly with the part on the left of this line.

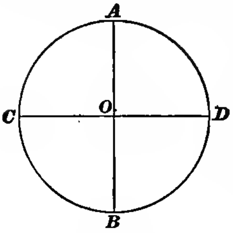


FIG. 34

It is evident from what has just been stated that a circle may have any number of axes of symmetry. In certain cases, however, a figure may be symmetrical with regard to only one axis. Thus, the isosceles triangle *A B C*, Fig. 35, is symmetrical with regard to the axis *B D*, because the part *B C D* would coincide with the part *B A D* if folded over on the line *B D*; but no other axis of symmetry could be drawn. A rectangle has two axes of symmetry at right angles to each other. A regular hexagon has six axes of symmetry.

72. **Similar figures** are those that are alike in form. As in the case of polygons, which have been considered, two figures, to be similar, must have their corresponding sides in proportion, and the angles of one equal to the corresponding angles of the other. Circles are, of course, similar figures.

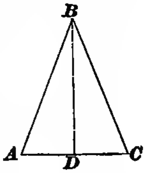


FIG. 35

73. *The areas of two similar figures are to each other as the squares of any one dimension.* Thus, a regular octagon whose sides are 1 inch long contains 4.828 square inches; another with sides 4 inches long contains 4^2, or 16, times 4.828 square inches = 77.25 square inches; for, let A = required area, then $A : 4.828$ sq. in. $= 4^2 : 1^2$, or $A = 16 \times 4.828$ square inches.

The use of this principle often saves considerable labor in determining the areas of similar figures, as, for instance, the end areas of frustums of pyramids, cones, etc.

74. The volumes and weights of similar solids are to each other as the cubes of any one dimension.

EXAMPLE.—If a cast-iron ball 9 inches in diameter weighs 100 pounds, what would a ball 15 inches in diameter weigh?

SOLUTION.— $100 : x = 9^3 : 15^3$, or

$$x = \frac{100 \times 3{,}375}{729} = 462.96 \text{ lb.}$$

The weight of the larger ball is, therefore, 462.96 lb. Ans.

STAIR BUILDING

CONSTRUCTION OF STAIRWAYS

CLASSIFICATION AND DEFINITIONS

1. General Considerations.—Stair building grew out of the necessity of securing an easy and safe passage from one level, or floor, to another. Such a passage might therefore be regarded in its inception as an inclined plane that connects two horizontal planes and is provided with a series of equal risers, or steps, formed for the purpose of giving a sufficient footing to facilitate travel.

The construction of wooden stairways is considered the highest branch of joinery; more care and knowledge are required in their planning, more ingenuity in setting them out, and more skilful workmanship in their execution, than in any other work about a building.

In studying the plan and treatment of a stairway, the architect should consider its adaptability for the building in which it is to be placed, its proposed location, the weight likely to come on it, the width to accommodate probable travel, and, especially, the ease of travel. It is not enough, as is sometimes done, to roughly calculate the treads and risers and sketch on the winders, leaving the stair builder to make the best he can of the conditions.

In designing stairways, the first and most important consideration is to arrange them so as to afford the greatest ease of communication to the stories with which they connect. Care should be taken to allow proper headroom for ascending and descending, and the treads and risers should be arranged

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so as to permit easy travel. The proper width of a stairway also has much to do with its appearance. In private houses, the width should never be less than 2 feet 8 inches, and in public buildings never less than 4 feet 6 inches. The staircase in which the stairway is enclosed should be given special attention, and the correct length and width should also be carefully considered. It is not conducive to sound construction to be obliged to cut out trimmer beams; neither is it good practice to have to piece out a few inches when the staircase has been framed too large.

The importance of proper arrangement of stairways is evident, when it is considered that they are seen by every one, their convenience and beauty being readily appreciated and their faults and defects instantly detected.

2. **Materials Used.**—In the construction of stairways, the most commonly used materials are stone, iron, and wood, and their selection depends on the location of the stairway and the use to which it is to be put. If the stairway is to be built on the outside of a building, stone is preferable, owing to its weathering qualities. If, however, the stairway is to be erected on the inside of a building designed to be fireproof, iron is generally employed, because of its better fire-resisting qualities. Either iron and stone is preferable to wood when used in public buildings where the amount of travel requires extra strength. Wood, however, is the material most commonly used, especially in private buildings, where no heavy travel occurs.

3. **Stair-Building Terms.**—In stair building, a *riser* and *tread* together are termed a **step**, the **riser** being the upright portion that supports the **tread**, or horizontal part, on which the foot is placed. The **nosing** is the projection of the tread beyond the face of the riser.

The term **run** is applied to the aggregate width of the treads.

Where the risers are parallel with each other on plan, thus forming straight steps, the steps are called **fliers**; but where the risers radiate on plan, the steps are called **winders.**

The term **flight** designates a succession of steps between one starting point and the one next above it. The spaces wider than steps, which constitute resting places between the flights, or which are the terminations of the stairways, are termed **landings,** or **platforms.** If the landing is square and occupies half the width of the stairway, it is called a **quarter-space landing;** but when it takes in the full width of the stairway, it is called a **half-space landing.**

The space required for landings is sometimes filled in by winders; this is especially the case in geometrical stairways and those in which the run is limited. Usually, the required rise and run in the given space decide the nature of the landing, whether it is to be quarter or half space, or filled in with winders. Where the run is unlimited, a half-space landing should be adopted; but where the run does not allow this kind of a landing, a quarter space is preferable to winders, as the latter should never be put in a stairway when they can be avoided.

When the lower step of a flight has its outer end in the form of a horizontal spiral, it is termed a **curtail step.** When the outer end of the lower step is rounded to a semicircle, it is a **bull-nose step.** Where steps have an outward curve, they are called **swelled steps;** this form is generally used when the front stringer is curved out at the starting of the stairway.

If, in ascending a stairway, the hand rail is on the right-hand side, the stairway is called a **right-hand stairway.** If the hand rail is on the left-hand side, the stairway is called a **left-hand stairway.**

The foregoing are some of the more common terms used in stair building; others will be explained as occasion arises for their use.

4. General Classification of Stairways.—Stairways are known as *dog-leg*, *open newel*, and *geometrical*. A **dog-leg stairway** has no well hole, and the face stringer of the upper flight is vertically over that of the lower one. A **well hole** is the vertical clear space between flights when the stringers of the return or upper flights are not located in the same vertical plane as the lower ones. The objection to dog-leg stairways is that the hand rail is not continuous, but strikes the soffit of the upper flight.

Where newels are placed at the angles of the well hole, the stairway is termed an **open-newel stairway;** but when the stringer is continued unobstructed by newels in a curve around the winders, the stringer is said to be *wreathed*, and the stairway is designated as **geometrical.**

5. The foregoing classification relates more especially to the general design than to the structural details, many of which are common to each. When classified with relation to the methods of construction, there are two systems: the first consists in the use of rough timbers, or *carriages*, cut to the angle of intersection between the treads and risers, as shown in Fig. 1; the other, which is more generally used, has the treads and risers tongued, or *housed*, from $\frac{1}{4}$ to $\frac{3}{8}$ inch, into the grooved stringers.

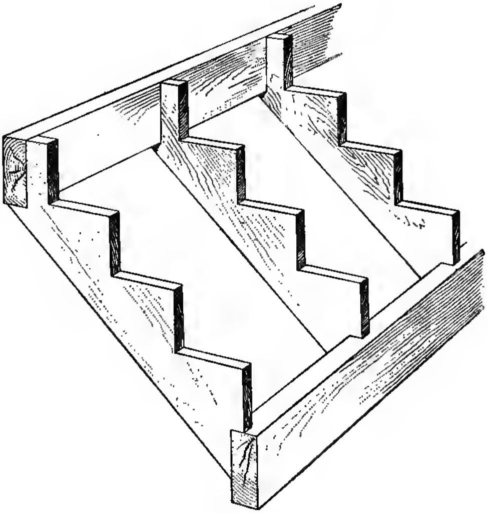


Fig. 1

In the first case, the treads and risers are nailed on the carriages, and, where they intersect with the wall, a board of the same thickness as the baseboard connecting with the stairway is *scribed*, or cut, to the required outline so as to fit closely the angles of treads and risers; this board runs the full length of the stairway, forming what is termed the **wall stringer.** In favor of this method of construction are its simplicity and strength. Against its adoption may be adduced the great difficulty of satisfactorily scribing the wall stringers, and even when this is successfully done, the stairway is likely, in time, through shrinkage and jarring, to show imperfections.

The carriages, also called *horses* and *springing trees*, for the second form of construction of stairways are not cut to the angle of treads and risers, as is the case in the first method, but are simply straight scantlings of sufficient strength to support the stairway and its probable load, rough brackets being nailed on the sides of these scantlings and fitted tightly under each tread and against the riser, as shown at *a*, Fig. 2.

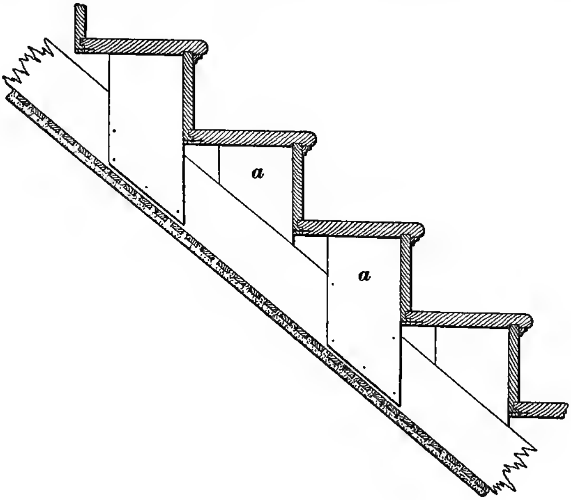


Fig. 2

6. In some cases, where the treads and risers are enclosed in stringers, the wall stringer only is housed to receive the treads and risers, the front, or outer, stringer being cut square to receive the tread and mitered to receive the riser. When thus prepared, the front stringer is termed a **cut-and-mitered,** or **open, stringer,** and the wall stringer is termed a **housed stringer.** Occasionally, both the wall and the front stringer are housed, in which case the front stringer is said to be a **box,** or **close, stringer.** Geometrical stairways are seldom thus constructed, the method being mostly confined to dog-leg and open-newel stairways.

In geometrical stairways, the front stringer is cut and mitered so as to meet the conditions arising from the wreathed portion of the stringer and rail, which are assumed to be parallel with each other in the same vertical plane. The rail in this case is supported by the balusters and starting newel, instead of by newels, and the cut-and-mitered stringer affords a substantial footing for the balusters, which are dovetailed, glued, and nailed to the ends of the treads, the nosing and molding of the treads being returned their full width on the face of the stringer. Stairs thus constructed are said to have *nosed-and-mitered moldings,* and when brackets are placed along the front stringer below the nosing, the stairway is known as a **bracketed stringer.**

DETAILS OF CONSTRUCTION

RISERS AND TREADS

7. Height of Risers.—In setting out a stairway, the first consideration should be to ascertain the exact height between the floors by measuring from the top of one floor to the top of the floor above. For this purpose, a rule, or rod, called a *story rod*, is sometimes used, on which the whole number of risers is to be marked. Care should be exercised in determining the risers, with the view of constructing a stairway that will have steps of convenient height. Experience teaches that a rise between 6 and 7 inches is the limit of easy stepping; therefore, in order to find the number of risers required, the total height of the story rod should be divided by either one of these figures. Having in this manner ascertained the number needed, divide the height of the story rod by the number of risers; the quotient will be the exact height of each riser.

8. Proportioning Treads and Risers.—The next step is to ascertain the width of the treads, not forgetting the rules of proportion between treads and risers, and always remembering that, owing to the landing not being counted as a tread, the number of treads in each flight is one less than the number of risers.

There are several rules for ascertaining the proportion that should exist between a tread and a riser for regular stairways and that determines not only the appearance of the stairway, but also the ease with which it may be traveled.

Three rules will be given, of which the first is the simplest and is generally preferred.

Rule I.—*Let the product of the tread and riser equal the number 66.*

For example, assume that the riser is 6 inches high, then the width of the tread will be 66 ÷ 6 = 11 inches. In the same way, the width of tread may be assumed and the height of the riser found.

Rule II.—*To any given height of riser in inches, add a number that will make the sum equal 12; double the number added, and the result will be the width of the tread in inches.*

For example, assume that the height of a riser is 7 inches; then 7 + 5 = 12, and 5 × 2 = 10, the width of the tread in inches.

Rule III.—*Draw a right triangle, as shown in Fig. 3, with a base of 24 inches and altitude of 11 inches. Mark the width of tread from a on line a b, as a c; at c erect a perpendicular, cutting the hypotenuse at e. Then c e indicates the riser.*

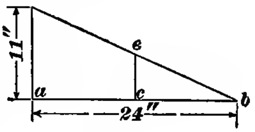


FIG. 3

HEADROOM

9. In trimming joists of staircases, the two cross-beams, which are called *headers*, should be so placed as to allow sufficient headroom to meet all probable requirements of a stairway. The header (which determines the headroom) should be placed so as to secure 7 feet of headroom from the tread vertically beneath it. A careful drawing of the elevation of the stairway will accurately determine this point.

In cases where a number of winders are placed at the bottom of a stairway, and the risers thereby stand one above the other at the center from which they radiate, a considerable rise is produced at the commencement of the run, the amount depending on the number of winders. In such a case, the header is placed at the extreme end of the staircase and thus ceases to be a factor in the headroom. This applies especially to *boxed stairways*, which are enclosed between partitions.

Care should be taken to make the staircase of the correct width, which should be at least 5 inches wider than the stairway; that is, the distance across the cylinder from the center of the rail of the flight to the fascia of the floor landing should be at least 5 inches, to permit the rail of the flight to pass clear of the nosing on the landing.

STRINGERS

10. Laying Out.—A straight stringer is laid out by means of a **pitch board**, which is shown in Fig. 4 (*a*). This board should be made of thin wood, the grain running parallel with the hypotenuse so that the effects of shrinkage will be the least possible. The base is cut to equal the tread, and the perpendicular to equal the riser.

In (*b*) is shown the stringer as marked out for the steps. The dotted line *a b* is drawn at a sufficient distance from the edge to permit the lower edges of the riser and tread to intersect on the line of the under side of the stringer, as shown at *d*; and on the line *a b*, distances equal to the slope length of the pitch board are stepped off with dividers. The pitch board may then be applied as indicated, and its outline marked on the stringer edges.

Templets, as shown in (*c*), should be made for the treads, risers, and wedges, care being taken that the pitches are alike, so that wedges of the same shape can be used. The lines *a d c b* show the section of the tread; and *a e f* shows the shape of the wedge. When applied to the stringer, the tread-and-riser templets should have their outer edges coincide with the lines made from the pitch board, giving the outline shown at *S*, Fig. 4 (*b*).

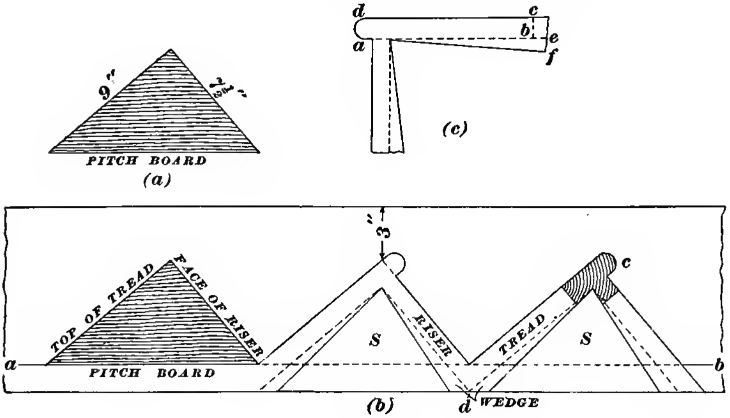


FIG. 4

11. To form the housing, holes are bored in the stringers adjacent to the nosing of the tread, as at *c*, Fig. 4 (*b*), and that portion is removed by means of a chisel. The lines of the templets may then be cut to the depth of the groove with a saw, and the material removed with a router plane.

Such a stringer is shown in Fig. 5, with the exception that the under edge is kept somewhat lower than the point *d*, Fig. 4 (*b*), and is preferable to the latter method in that the wedges are well supported at their outer ends. If the staircase will allow the insertion of the assembled parts, the treads and risers are attached to the stringers, wedged and glued into the housing, and the whole taken bodily to its

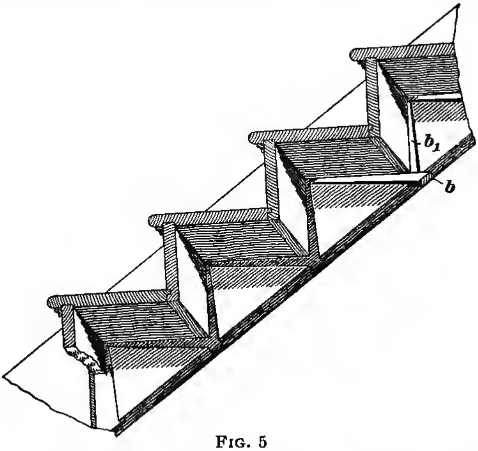


FIG. 5

place in the building. The wedges are shown in place at b and b_1, Fig. 5.

12. The wall stringer, as shown in Fig. 6, and also the front stringer, if a close one, are each grooved as already explained, the depth depending on the thickness of the

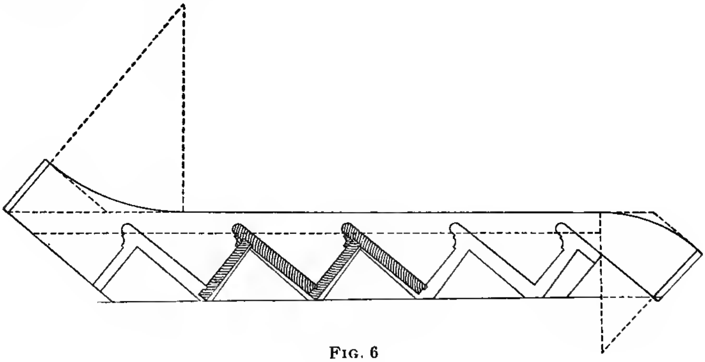


FIG. 6

stringer. Two or more carriage timbers are used in the width of the stairway, the number, depth, and thickness depending on the width of the stairway and the load to be carried.

The front stringer, as shown in Fig. 7, is well nailed to the front carriage timber *a*, while the other timbers are rough-bracketed under each step alternately on the sides, and nailed as shown at *a*, Fig. 2. A furring strip to receive the lath is nailed to the wall in line with the lower edge of the carriage timbers. The prepared mortised wall stringer is nailed to the wall to square properly with the previously set carriage timber and front stringer.

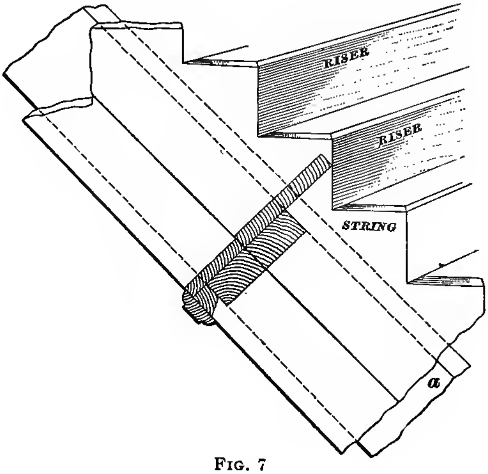


Fig. 7

13. Scribing Wall Stringers.—When the treads and risers are supported by rough-cut carriages, it becomes necessary to cut a wall stringer that will fit around the steps and make a finish with the wall. In Fig. 8 is shown a method of *scribing* a wall stringer. The stringer is represented as being laid with one edge on the line of the nosings, and the instrument to be used is shown in position. The hardwood or iron bar *b h* has a hook on the lower end, which projects sufficiently to enable the bar to clear the nosing when the point *b* is touching the face of the riser. The bar *b h* is placed against the guide *m*, being loosely bound to it by the metal straps *e* and *k*. The strip *n* is fastened to *m* by a bolt *a*, which can be tightened so as to preserve the bevel. A small nick is made in the sliding bar *b h* at *c*, so that *b c* is the height of a riser. When the point *b* is on the end of the nosing, the nick *c* gives the position of the corresponding point on the wall stringer, which may be marked with a steel point, or pencil. Other points may be found in a similar manner, and the outline to which the wall stringer is to be cut can then be drawn.

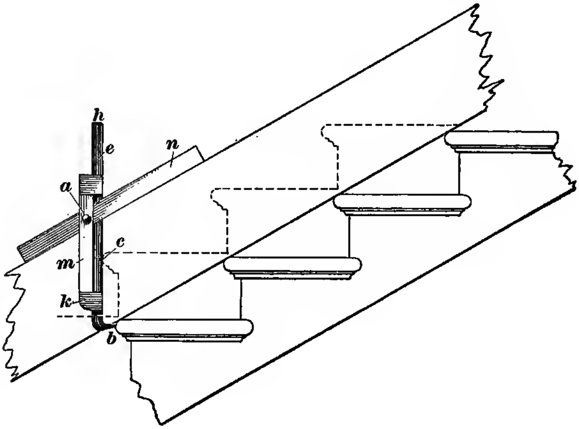
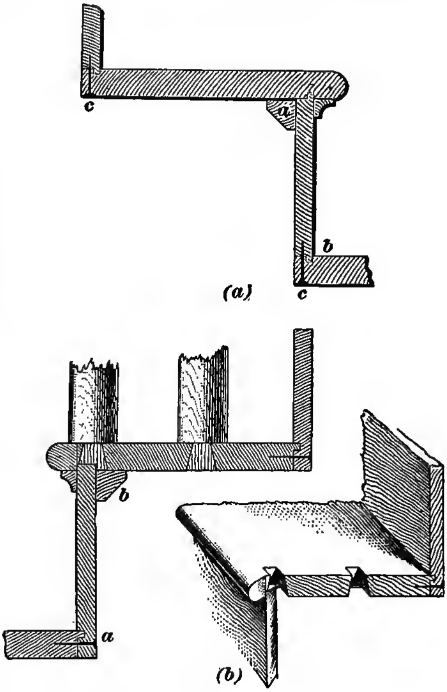


Fig. 8

CONSTRUCTION OF STEPS

14. In constructing steps, a portion of the upper edge of the riser may be tongued into a groove in the under side of the tread, as shown at *a*, in Fig. 9 (*a*), instead of letting the whole thickness of the riser into the tread, as shown at *b* in (*b*). The lower edge of the riser may also be tongued into a groove in the upper surface of the tread beneath it, as shown at *b* in (*a*), in which case the tread will have to be nailed up into the riser as at *c*; this method, however, does not give such good results as that shown at *a* in (*b*).

The finished treads and risers are glued together, being clamped with handscrews until the glue has set. From two to four well-fitted blocks are then glued and nailed to the internal angle of the tread and riser, as shown at *b* in (*b*). In Fig. 9 (*b*) are also shown the dovetails for inserting the balusters.



(a)

(b)

Fig. 9

15. Bull-Nose Steps.—A form of step that is much used is illustrated in Fig. 10. A solid or built-up block of wood is sawed into the shape shown at *e*, and the riser is sawed out as indicated, leaving a veneer to cover the face of the block. The end *b* is firmly fastened to the solid block with screws. At *a*, a square hole is left the full depth of the riser, into which wedges are driven from each end, as suggested at *d*. The back of the veneer is covered with glue, and as the wedges are driven home it is clamped firmly against the face of the block. The newel is generally set on top of this step, as indicated by the dotted lines. The second riser may be placed in line with the middle of the newel, as indicated at *c*, or in any other position desired.

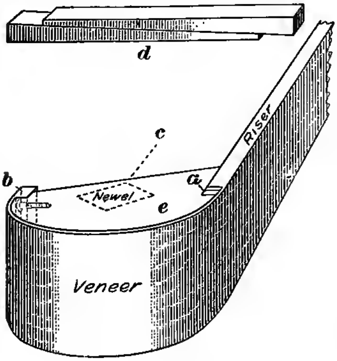


Fig. 10

16. Curved Risers.—Where risers are curved, they should be made of solid wood, or of curved strips of seasoned wood glued solidly together. Frequently, however, seasoned wood in pieces large enough to make a solid curved riser cannot be secured. In such cases it becomes necessary to bend pieces of 1-inch board by kerfing. The method of finding the distance between kerfs for a curve of given radius is as follows: Cut one kerf, as at *a*, Fig. 11; then, marking the distance *a d* equal to the radius *a o* of the curve to which the piece is to be bent, bend the board to position *a b* until the saw kerf is closed, as shown. Measure the distance between *d* and *b*. This length *d b* is therefore the distance between kerfs, which, if continued, will shape the board to the curve *a e*. All the kerfs must be made with the same saw and to the same depth.

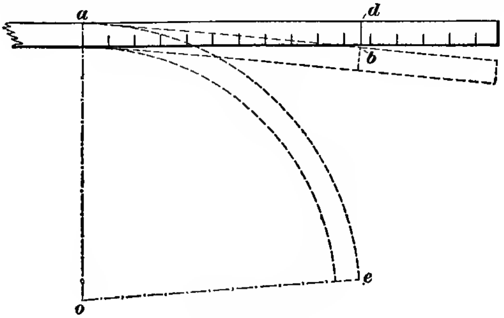


FIG. 11

17. Platforms.—Where the stairways of a building are of considerable length and are straight in plan, it is best to break the flight by a platform, which may be projected from the side wall, as shown in Fig. 12. In a brick wall, the

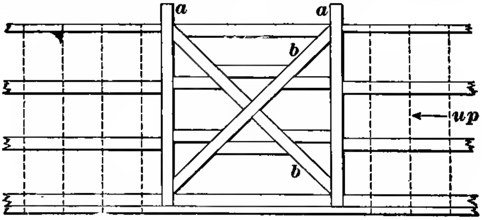


FIG. 12

lookouts *a*, *a* should be set in at least 8 inches, with slip keys tightly wedged between the bricks and the top of the timbers. In frame walls, the lookouts are nailed to the studs. The braces *b*, *b* should be well fitted and spiked to the lookouts. These braces serve to keep the platform square, and should be made of thoroughly seasoned wood. A flight terminating in a platform should not contain more than twelve steps. A perspective sketch of the platform is shown in Fig. 13.

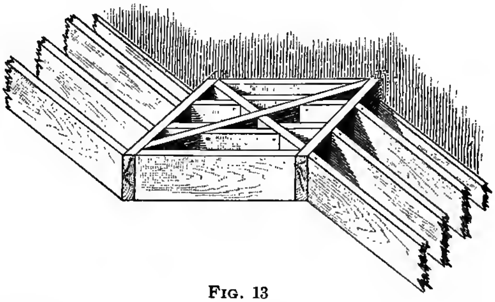


FIG. 13

CYLINDERS

18. In a geometrical stairway, the hand rail, when not obstructed by newels, sometimes travels over six or more flights from the first step to the last; it then becomes necessary to wreath the stringer and rail around the well hole. The well hole thus treated is said to contain a **cylinder**, which is the curved space around which the hand rail and stringer are wreathed. In a circular stairway, the cylinder assumed has a complete circle for its plan, and the stringer and rail are made to wind around it, following a curve termed a *helix*—a curve of the same nature as the winding thread of an ordinary screw. The finished treatment of the stringer and balustrade is continued around the cylinder, and where the stairway terminates in a landing, the same treatment is continued along the trimmer beam. The finishing piece on the face of a landing beam corresponding to the stringer of the flight is called the *fascia*. Thus, it will be seen that the stringer of the flights, the cylinder of the well hole, and the fascia of the trimmer beam are but parts of one continued stringer known by different terms.

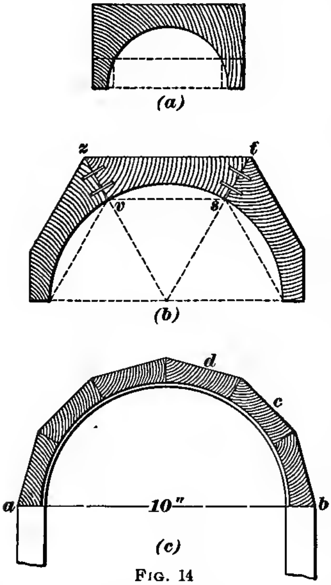


FIG. 14

19. Cylinders are built up as shown in Fig. 14. The construction shown at (*a*) is used for small cylinders, while for larger ones, the methods shown at (*b*) and (*c*) are used. The joints, as *s t* and *v z*, are glued and strengthened by screws or wooden dowel-pins. For extra-fine work the face of the cylinder is veneered, so that the joints of the staves in the semicircle from *a* to *b*, in (*c*), are covered. The veneer is bent over a skeleton cylinder whose diameter is equal to that of the well cylinder, and then backed with properly fitted staves, as *c* and *d*, well glued, and screwed or doweled at the joints, if necessary.

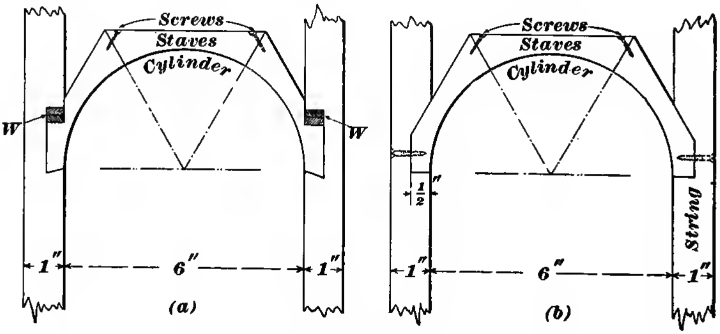


FIG. 15

The end staves of small cylinders are fastened to the stringers in various ways. Two common methods are shown in Fig. 15. In the first method (*a*), a dovetailed groove is cut in the stringer into which the end stave fits. Wedges *W*, glued in, hold the stave in place. In the second method (*b*), the end staves are merely set into the stringers and screwed fast from the outside.

MISCELLANEOUS DETAILS

20. Moldings.—All base and stringer moldings should be worked out of solid wood. Work that is to be bent is generally stronger when laminated, as shown in Fig. 16; but for moldings this method cannot always be used, since the joints will show no matter how well the work is done. This is particularly true of hardwoods. If the work is to be painted, however, this method is not objectionable.

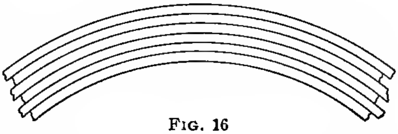


FIG. 16

21. Erection.—If the stairway is put up against the brown-mortared wall, the finished parts must be well covered with building paper. Rough boards should also be placed on the treads and allowed to remain there until the interior woodwork and plastering are completed. The covering, however, should be fixed in such a manner that enough of it can be easily removed to permit the erection of the hand rail and balusters.

When the steps are set in place, they should be carefully inspected to ascertain if any of them are cut short and pieced, if any of the wedges are improperly glued, or if the nailing of treads and risers is omitted. The stairway should make no creaking noise when a person ascends or descends; even a slight creaking is sure to grow louder in time, and thus be a lasting reminder of defective work. Creaking is generally due to defective gluing, nailing, wedging, or to the use of unseasoned stuff in the rough carriages and brackets, or in the finished material.

BALUSTRADES

22. Newels.—Newel posts, or **newels,** are used to support the hand rail, and are either made of solid materials and turned, or are built up box-like, in which case they are called **box newels.** They vary in design, form, and size, some—especially the one placed at the bottom of the stairway, called the **starting newel**—often being elaborated with panels and carving.

The newel is also variously fixed in its relation to the steps adjoining; in ordinary cases, it is placed on the floor, and when so placed its center should be in line with the center of the first riser. Where space is limited at the bottom of a stairway, the newel may be placed on top of the first step, or even on top of the second or third step; but in each case, it should be so placed as to have the center of the riser in line with the newel center, and the steps outside rounded and returned into the stringer. The end of the latter is inserted into a prepared mortise in the center of the newel.

The **angle newels** on the landings are generally smaller in size and are treated simpler than the starting newels. The same rule applies to their relation to the risers; namely, that the center of the riser should be in line with the center of the newel. Working from centers in stair-building construction is almost a maxim. The center of the rail is to be in the center of the newel; so, also, is the center of the stringer. The center of the baluster is to be in the center of both the stringer and the rail, and, as stated before, the center of the riser adjoining the newel is to be placed at the center of the latter.

23. Balusters.—Balusters are small columns, generally turned, that are set vertically on the ends of treads or on the stringer, forming an ornamental guard and supporting the hand rail. When the front stringer is closed, or housed, the balusters are fixed to the stringer instead of to the treads, a grooved molding, called a *cap*, being prepared to receive them. The lower ends of the balusters in this case are cut to the pitch of the stairway, and the top is either cut to the same pitch as the rail or is mortised into it. This applies to balusters having square ends. Frequently, they are made square or round at the bottom and turned to a spindle shape at the top, being then termed **pin balusters.** Balusters with square bases are preferable to those with round bases, as the bearing surface and resistance to movement of a square base is almost double that of a round base. Holes are bored about an inch deep into the under side of the rail to receive the balusters, and the lower ends of the balusters are either cut to the pitch of the stairway or are dovetailed to the ends of the treads, depending on whether the stringer is housed, or cut and mitered.

In ordinary stairways, two balusters are placed on each tread, but in the better class of stairways, the number is increased, thereby adding to the beauty and strength of the balustrade and to the general appearance of the stairway. The two balusters on a tread are placed half the width of a tread apart between centers, the short one standing close to the nosing and the long one being placed midway between the adjacent nosing balusters, so that it is exactly one-half the rise of the steps longer than the short baluster on the same tread. The usual height of pin balusters is either 2 feet 4 inches or 2 feet 8 inches, of which 1 inch is allowed at each end for insertion into the rail and the tread

In some stairways, the space between the balusters is filled in with brackets of various designs or is paneled. In either case, the number of balusters is reduced to one for each tread, ordinarily placed over the face of each riser, thus leaving the full width of the tread (less the thickness of one baluster) for the decorative brackets or panels.

24. Hand Rails.—The development of hand rails, which involves complex geometrical problems, is not within the province of the architect or builder, though a few remarks regarding their construction are pertinent. Except where the rail is placed over winders, whether at the bottom of the stairway or around the cylinder in the well hole, it should be set parallel with the line of nosings. The inclination of the pitch will be greater over the winders than over the straight rail, and as this determines the height of the rail, it follows that any addition to the pitch over the winders will require more height for the wreath. This additional height, however, should never be such as to cause an unsightly crippled appearance where the curve of the wreath intersects with the straight rail. In stair construction, each baluster should be set vertically and be glued solidly and nailed to the hand rail, so that when tested there shall be no noise, which would indicate the presence of loose balusters through imperfect fitting, poor gluing, or carelessness in nailing.

Where the straight rail enters the newel without a ramp, the newel may be made from 4 to 6 inches shorter than would otherwise be possible, the reduced height often being a matter that should be taken into account. Where such is not the case, the hand rail may be bent upwards (in which case it is said to be *ramped*), so as to enter the newel in a plane perpendicular to it, and the angle of intersection between the raised level portion and the inclined plane of the straight rail is gracefully eased. This last method is the one most commonly adopted, owing to its better appearance.

25. Ramps and Easements.—In an open-newel stairway, the rails usually meet the newels one above the other. To bring the rails to the same level, they must be ramped, and sometimes they are ramped and *kneed*—the latter being a concave easement with its upper end forming an angular knee. When the knee is convex, the combined curve is called a *swan neck* or sometimes a *goose neck*. The lower ends of rails abutting against the newels may be either straight or curved. When curved, the rail is said to be *eased*, and the curved portion of the rail is called the **easement**. This arrangement, however, requires the newel to be somewhat longer.

26. Stiffening Hand Rails.—Continued hand rails are sometimes provided with an iron brace that extends across the cylinder from the fascia to the bottom of the rail. Instead of this brace, an iron baluster is often placed at each end of the wreath. Fig. 17 (*a*) is a perspective sketch of the base

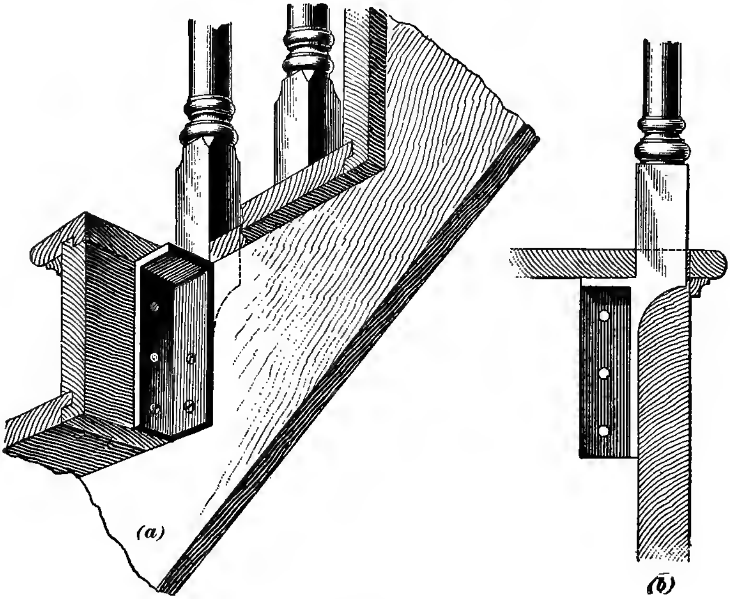


FIG. 17

of such a baluster, which is formed into a flanged connection and attached to the riser and to the stringer by screws. At (*b*) is shown a side elevation of the base and its relative position with reference to the face stringer.

GENERAL STAIRWAY DESIGN

ORDINARY FORMS

27. Step Ladders.—One of the simplest forms of stairways in use is a fixed or movable **step ladder**, such as is sometimes built from an attic floor to the roof, and shown in Fig. 18, where (*a*) is a plan, and (*b*) an elevation. The top step should always have an increased width, and the sides of the ladder should be at least 6 inches wide by $1\frac{1}{8}$ inches thick. The steps are *gained* into the sides not less than $\frac{3}{8}$ inch, and are securely nailed or screwed thereto. As shown in the figure, this ladder rises 8 feet, or 96 inches, which, divided by 10, the number of steps, gives $9\frac{3}{5}$ inches for each riser. The horizontal distance from the face of the landing beam to the bottom of the ladder equals 3 feet 7 inches. This distance, less 3 inches for additional width of top step, leaves 3 feet 4 inches, or 40 inches, which, divided by 10, the number of treads, gives 4 inches as the width of each tread from its nosing to a vertical line dropped from the nosing above.

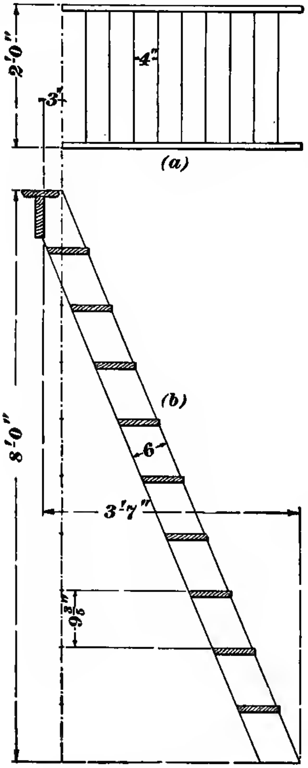


Fig. 18

28. Plank Stairway.—In Fig. 19 (*a*) and (*b*) are shown the plan and elevation of a strong **plank stairway**, such as

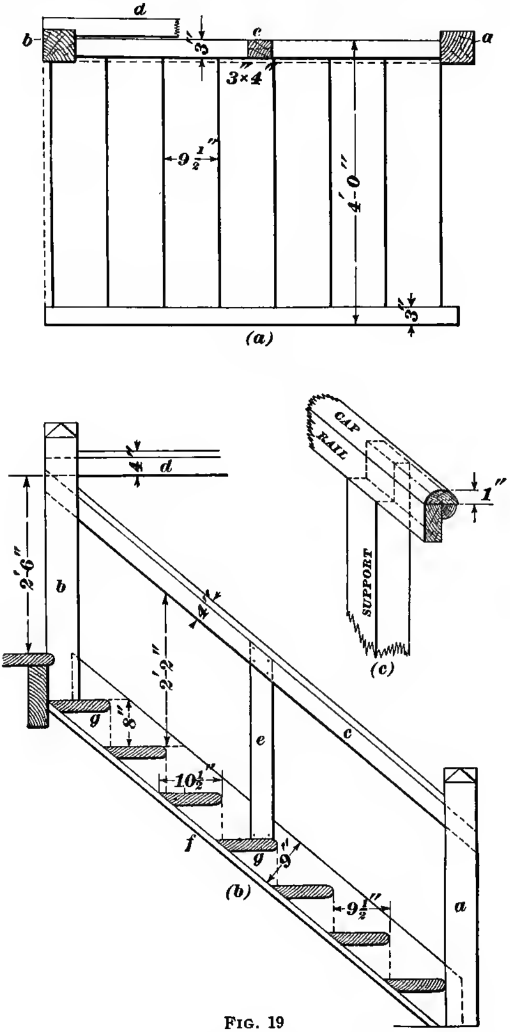


Fig. 19

may be required for a shop or factory; *a* and *b* are newels, 6 inches square, to which 3" × 1½" hand rails *c* and *d* are fastened and braced with one or more uprights *e*. In (*c*) is shown a section of the hand rail. As shown in (*b*), hardwood treads *g*, 2 inches thick, are mortised 1 inch into 3-inch timber stringers, tightly fitted into the mortises, and well spiked, but not wedged. The soffit may be ceiled with matched lining, as at *f*.

GEOMETRICAL STAIRWAYS

29. Straight Stairways.—In Fig. 20 are shown the plan (*a*) and elevation (*b*) of a **straight stairway** with a

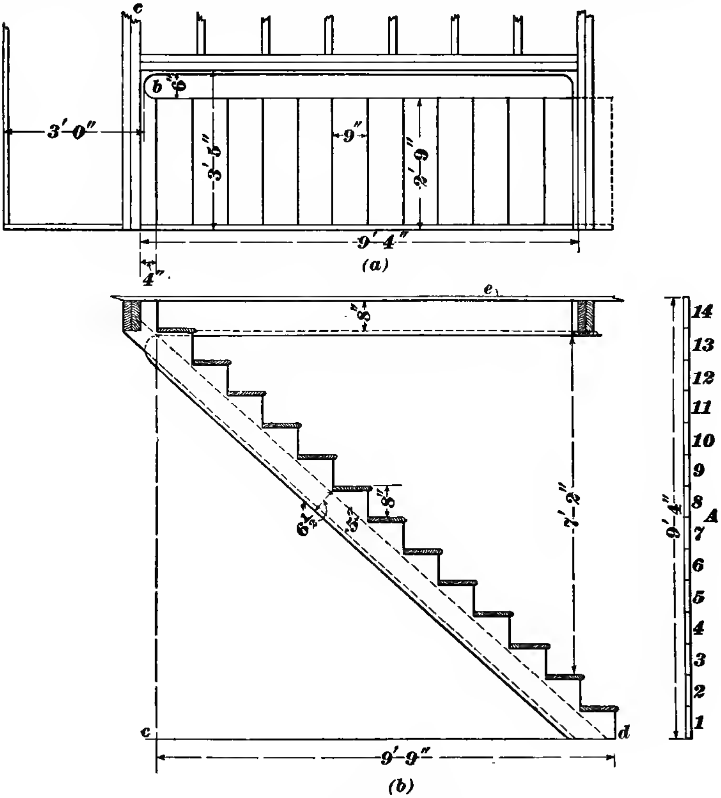


FIG. 20

6-inch cylinder. The first requirement in planning this stairway is to fix the number and height of risers. The story rod *A* indicates the height of the story to be 9 feet 4 inches, or 112 inches, which, divided by 14, the number of risers, gives 8 inches as the height of each riser. The total run *c d* is 10 feet 1 inch, less 4 inches for the depth of the cylinder, which leaves 9 feet 9 inches to be divided into thirteen treads, giving 9 inches as the width of each tread. As the floor at the landing makes one of the steps, there is one tread less than there are risers. The width of the stairway, shown in (*a*) as 2 feet 9 inches, is measured from the face of the plaster to the face of the front stringer, while the width of the well includes the width of the stairs, the diameter of the cylinder (in this case, 6 inches), plus 1 inch for the thickness of the fascia, and 1 inch for lath and plaster—altogether 3 feet 5 inches; and, if the outside wall is constructed of brick, 1 inch more for thickness of furring will be required. At the landing of a straight flight, there must be at least as much room between the cylinder and the partition as the width of the stairway, preferably as much more as possible. In this case, 3 feet is the width used in the platform, the 3 inches extra being allowed for convenience in moving furniture, etc.

The headroom of the stairway shown in Fig. 20 is 7 feet 2 inches from the top of the second step to the ceiling, and the point where this headroom can be secured governs the length of the well hole, which as figured on the plan, is 9 feet 4 inches. It is not necessary to make a drawing of the elevation in order to find the length of the well hole for the required headroom, as this can be calculated from the plan by counting twelve risers down. If each riser is 8 inches, the twelve risers make 96 inches. From 96 inches subtract 10 inches, the depth of the floor, giving 7 feet 2 inches as the headroom. The twelve treads of 9 inches each make 9 feet, to which must be added 3 inches for the depth of the cylinder and 1 inch for its thickness, making the total length of well hole 9 feet 4 inches.

The hand rail for such a stairway as this would be from 3 to 3½ inches wide, and the balusters from 1½ to 2 inches, square or turned.

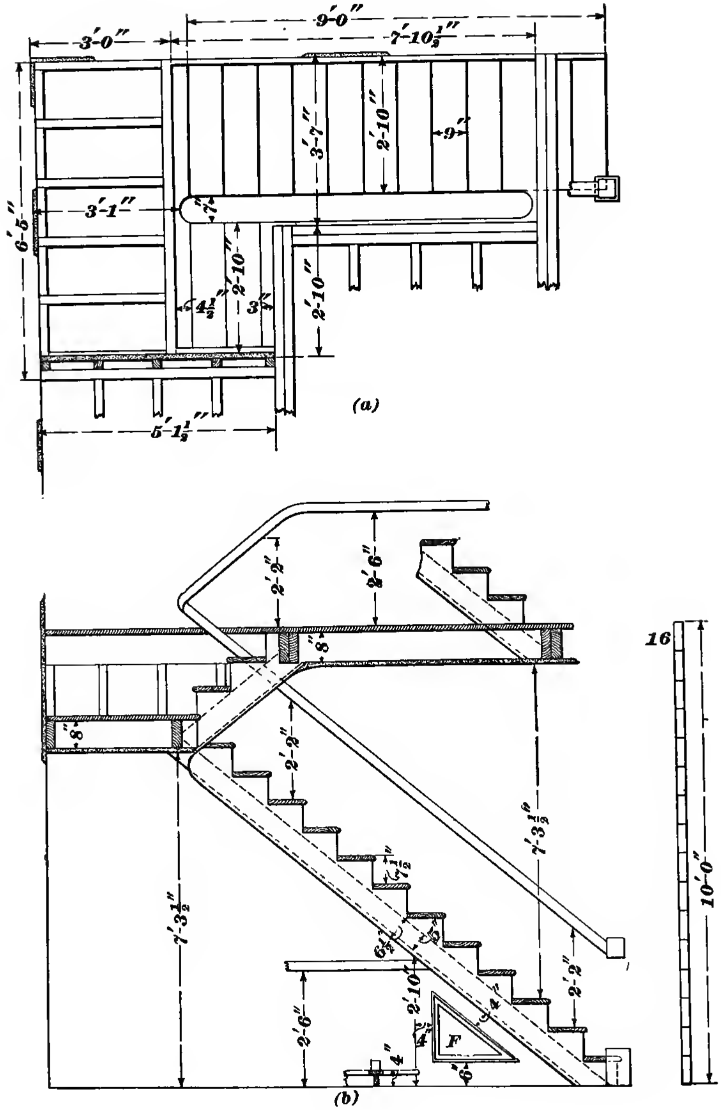

9'-0"
3'-0"
7'-10½"
6'-5"
3'-7"
2'-10"
9"
3'-1"
7"
2'-10"
2'-10"
4½"
3"
5'-1½"
(a)
2'-2"
2'-6"
8"
8"
16
2'-2"
7'-3½"
10'-0"
7'-3½"
7½"
6¼"
5"
2'-10"
4"
2'-2"
2'-6"
4"
4"
F
6"
(b)

FIG. 21

30. Platform Stairways.—In Fig. 21 is shown the plan (*a*) and the elevation (*b*) of a **half-turn platform stairway**, with a continued hand rail around a 7-inch cylinder. A stairway of this kind is easy to ascend, as the flight is broken by a roomy platform. This arrangement also provides space for a window to light the stairway and hall from above the platform, while below it affords room for a doorway to the outside. With the latter purpose in view, the soffit of the platform must not be less than 7 feet in height. The plan also indicates the timber framing of the well and the platform.

A jib panel *F* is shown at the start of the stairway in the elevation (*b*), the object of which is to close and neatly finish the angular space formed by the intersection of the stringer and the floor. The height of the jib panel is such as to receive the hand rail of the basement stairway. Where it is desired, the latter stairway may be enclosed by a paneled or lath-and-plaster partition extending up to the stringer of the upper flight.

The hand rail on the flight is 2 feet 2 inches in height from the center of the short baluster at the top of the step to the bottom of the rail. Along the hallway, the bottom of the rail is 2 feet 6 inches from the floor. These heights are based on the commercial custom of turning ordinary pin balusters in lengths of 2 feet 4 inches and 2 feet 8 inches, 1 inch being allowed for entering the hand rail and 1 inch for the dovetail entering the tread, thus leaving the exposed part the length mentioned.

The half-turn platform stairway can be altered in various ways without changing the number of risers. For instance, a step can be taken from the upper flight and added to the lower flight, increasing the run 9 inches and raising the platform one riser, making it 7 feet 11 inches. Then the well hole for the same headroom must be 9 inches longer, and the beam at the landing of the short flight must be brought forward the same distance. On the other hand, a step may be added to the short flight, making four risers in the short and leaving twelve risers in the long flight. The well hole can now be shortened 9 inches and still have the same headroom as before; but it will be necessary to move the landing beam of the short flight back 9 inches to accommodate the additional step. The platform, however, is one riser lower, making it 6 feet 8 inches; but, if the total depth of the platform can be made 6 inches, thus reducing its depth 4 inches, the height of the soffit of the platform will be 7 feet.

31. Winding Treads.—In Fig. 22 is shown an **enclosed stairway,** illustrating the method of laying out the wall stringer, easement curves, etc. The widths of the winding treads at the wall are projected down from the plan by lines *k l*, *m n*, etc. Then, the wall stringer *a b*, at right angles to the main wall stringer *a e*, is revolved, as shown, parallel with the main wall stringer, and laid out in a similar manner; *a' b' c' d'* shows the stringer *a b* in elevation. The stringer *e f* is treated in a similar manner. The story rod is shown at the left, and the steps are projected from it and from the plan, as shown at step *4*. Where the treads are wide, as in steps *1*, *2*, and *3*, the line of the nosings makes an angle with the horizontal different from that made by the line of the nosings in the body of the stairway. This is because the uprights, or risers, remain the same, while the horizontals, or treads, vary in width.

32. Easement Curves.—At the angles, easement curves are necessary, or, at least, advisable. At *h*, Fig. 22, is shown a method of drawing an easement curve. From the vertex *h* lay off equal distances in both directions, as *1*, *2*, *3*, *4*, etc. Draw lines from *5* to *6*, *4* to *7*, etc. Through the points of intersection of these lines, draw a curved line by means of a spline. If the angle is sharp, as at *g*, perpendiculars may be drawn at equal distances from *g* until they intersect, as at *o*; the curve can then be drawn with compasses.

33. Items of Detail.—In winding treads, both wall and front stringers are to be mortised, or housed. For the steps, the treads and risers are to be glued together, wedged, and back-nailed, as before explained, in order to secure good,

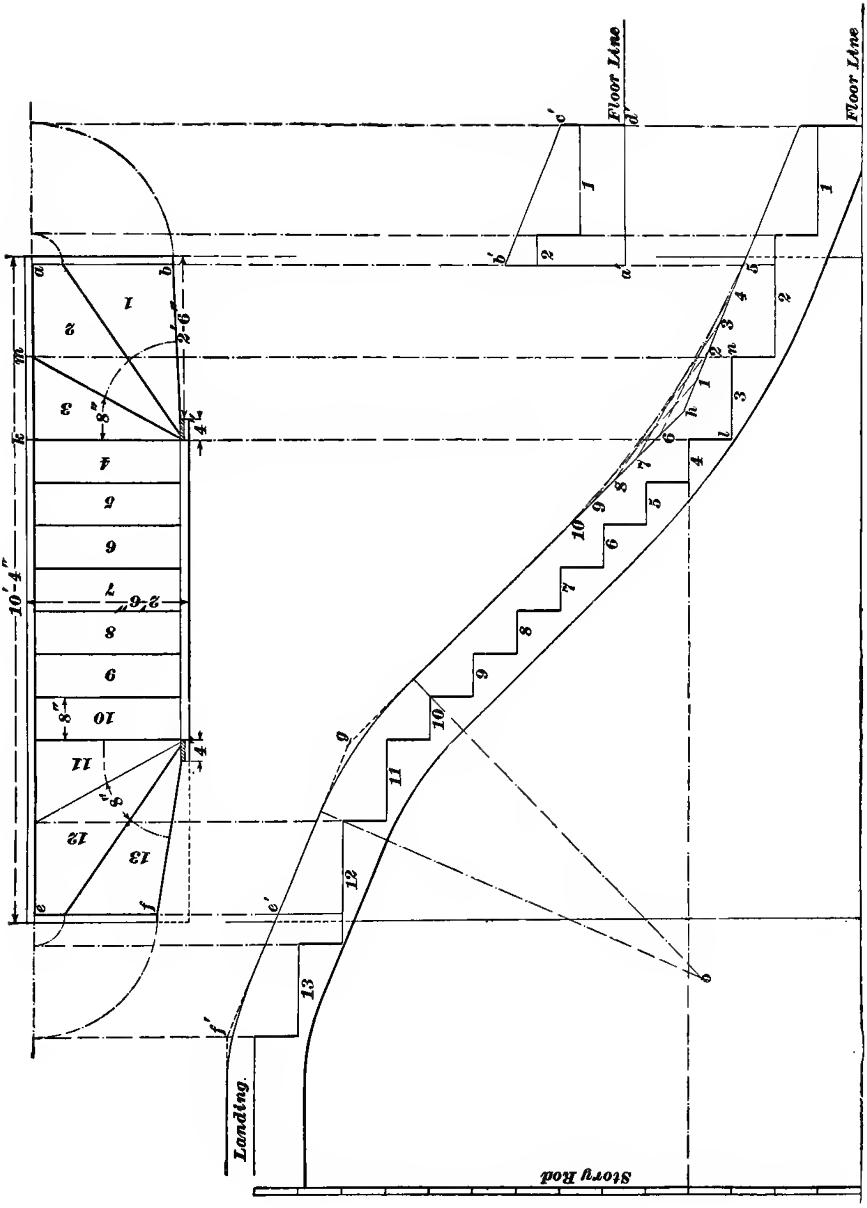

Floor Line
Floor Line
Landing
Story Rod
10'-4"
2'-6"
2'-6"
8"
8"
8"
4
4
a
b
m
k
e
f
c'
d'
b'
a'
e'
f'
g
h
l
n
o
1
2
3
4
5
6
7
8
9
10
11
12
13

FIG. 22

solid work. The front stringer should have a vertical strip 4 inches wide spliced and glued to it, so as to receive the winders. The well must be framed wide enough to include, besides the figured width of the stairway, the thickness of the enclosing lining.

34. Double Winders.—In Fig. 23 is shown a stairway winding one-quarter turn at the top and the bottom, with an 8-inch cylinder for a continued hand rail. In planning winding stairways, it is important to make the treads as nearly as possible of the same width on the line of travel. This line should be about 14 inches from the face of the stringer, as shown on the plan (*a*). The width between finished walls for this stairway should be at least 6 feet 4 inches. as follows:

Width of stairway from finished wall . .	2 ft. 10 in.
Diameter of cylinder	8 in.
Hall passage	2 ft. 10 in.
Total	6 ft. 4 in.

The distance from the finished wall to the cylinder is made 3 feet 1 inch, so as to allow room for moving furniture. Where the stairway is continuous, the first and last risers of each flight should be placed 2 inches beyond the landing fascia line, in order to make a proper finish with the fascia.

In commencing the drawing, the starting and landing risers are marked on the plan, and the line of travel is divided equally, as before mentioned. Then, the space along the cylinder is divided; and, lastly, the risers along the straight stringer are drawn in position. Lines are drawn through the points found along the line of travel and passing through the points located along the front stringer, thus completing the plan of the stairway. The elevation (*b*) of the stairway is drawn by projecting the lines of the risers down from the plan and by drawing the lines of the treads horizontally from the story rod, as shown at tread *10*. For the development of the wall stringer, the method given in Fig. 22 should be followed. The headroom, as shown in

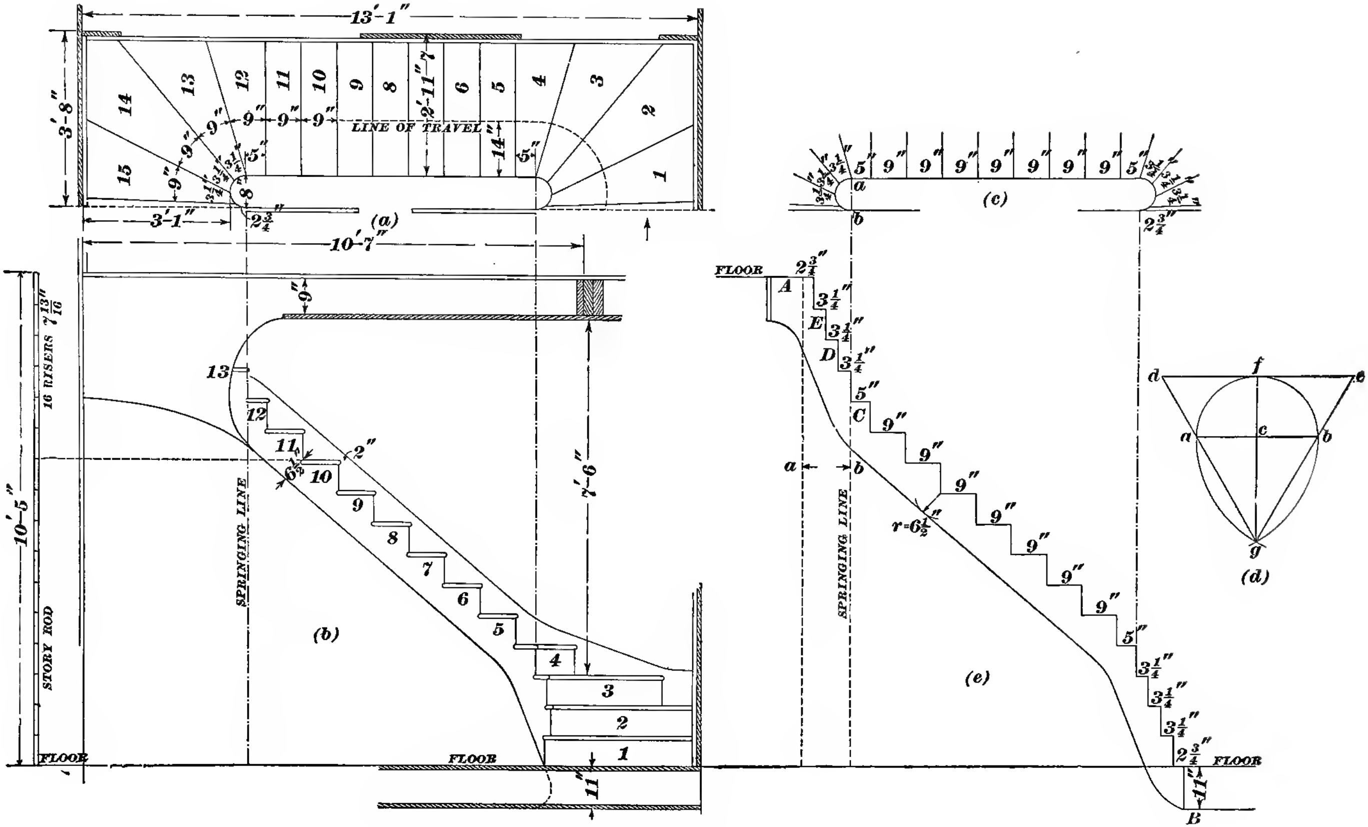

13'-1"
3'-8"
3'-1"
2¾"
(a)
LINE OF TRAVEL
2'-11"
14"
5"
9"
10'-7"
9"
7'-6"
10'-5"
16 RISERS 7 13/16"
STORY ROD
FLOOR
SPRINGING LINE
(b)
2"
6½"
11"
(c)
FLOOR
A
E
D
C
B
3¼"
5"
r=6½"
a
b
(e)
d
e
f
c
g
(d)

FIG. 23

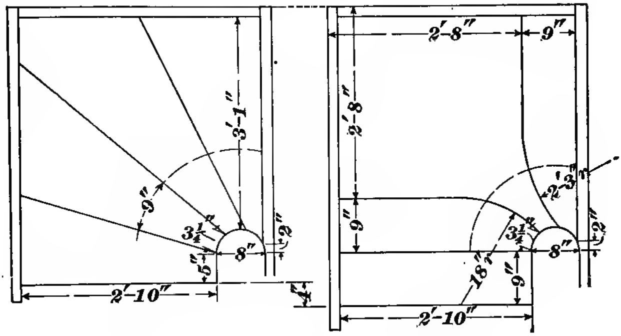
Fig. 23 (*b*), is 7 feet 6 inches from the top of the third step to the ceiling.

35. Width of Winders.—The winding treads must be made of uniform width around the cylinder, so as to obtain a uniform curve in the rail. It will be observed, in Fig. 23 (*a*), that there is a 5-inch width introduced between the straight flight and the cylinder, which provides for a better easement, or ramp, from the pitch of the straight rail into the steeper pitch of the wreath rail; besides, if the winders were all contained in the cylinder, a sudden and abrupt change of inclination in the stairway would be made, thus causing one to stumble and fall.

36. Development of Stringers.—In Fig. 23 (*c*) and (*e*) are shown the methods of developing the front stringer when each end curves around a cylinder. The plan (*c*) of the front stringer is the same as in (*a*). The distance *a b* in (*e*) is equal to the "layout" of the semicircular cylinder, found as in (*d*), where *d e* is the *outstretched*, or developed, length of the curve *a f b*. The length of *d e* may be determined as follows: Make *a b* equal to the diameter of the cylinder. From *c*, with a radius equal to one-half of *a b*, describe an arc *a f b*; from *a* and *b* as centers, with a radius equal to *a b*, describe arcs intersecting in *g*. From *g*, through the points *a* and *b*, draw lines *g d* and *g e*; through *f* draw a line tangent to the arc and parallel with *a b*. The points where this line intersects with the lines drawn through *g* will define the length of *d e*, or the developed length of the arc *a f b*.

A C B in (*e*) is the front stringer, any outstretched step, as *C*, being obtained by projecting the line of the riser vertically from the plan, and the tread horizontally from the story rod. As the steps *D*, *E*, etc. in the cylinder have their width marked on the plan as 3¼ inches, that width is therefore transferred to the development. The stringer in this case is 6½ inches, measured from the angle between the treads and the risers. This width is marked out with compasses from each angle, and a pleasing curve is drawn tangent to the arcs, as shown. When a cylinder is of this diameter, or smaller, at the bottom of the flight, the curve of the hand rail presents a better appearance, and it is more convenient when the rail over the regular treads is continued on its pitch into the wreath without ramping the straight rail. In this case there would be an easement introduced between the straight rail and the wreath piece.

37. Arrangement of Winders.—In Fig. 24 are shown the plans of two different stairways brought together for comparison, each having one-quarter turn with an 8-inch cylinder and a continued hand rail. It will be seen that a platform is obtained by the arrangement shown in (*b*), thus making the flight much more desirable. In the plan (*a*) there are four winders, differing but little from the plan shown in Fig. 23; while in (*b*) there are three winders with slightly curved ends. The five risers so changed in their arrangement in (*b*) take 4 inches more run than the plan with four winders, as shown. The placing of the carriage timbers in such stairways is a matter that requires care, as the strength and stability of the stairway depends largely thereon.



(*a*) (*b*)

FIG. 24

38. Carriage Timbers.—In Fig. 25 is shown the plan of the top winders of a stairway similar to that shown in Fig. 23, *a*, *b*, and *c* being the principal timbers in position.

The timber *a* is set in place after the stringers are put up, being nailed to the floorbeam at *d* and fastened to the wall at *e*. A piece of furring strip held in the direction *e d*, together with a straightedge tried along the line of the risers, will indicate the best position for this timber.

The bottom of the flight, as shown in Fig. 26 (*a*), may be timbered by securely placing a level piece *f k* extending from the front stringer into the wall, and then the two timbers *g h* and *l m* at a steeper pitch than the main timbers *n* and *o*. To do this may require the insertion across the well hole of the floorbeam *j i*; this is shown by the elevation at (*b*), where *l m* and *g h* of the plan are seen at *g′ h′*, and *n* and *o* at *n′*. Or, instead of timbering in this manner, omit the level piece *k l* and place a diagonal timber *i k* at the top, continuing the principal timbers *n* and *o* to meet it. The remaining timbers are filled in as required for furring, which must be done so

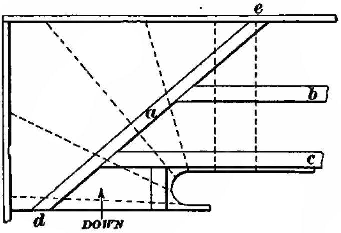
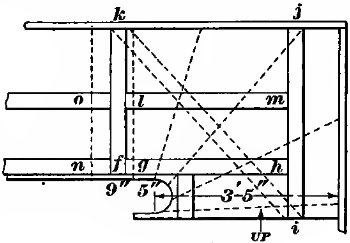
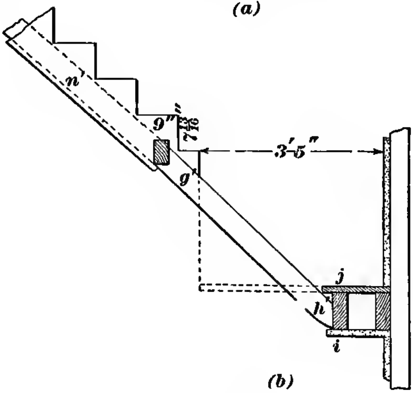


FIG. 25



(*a*)



(*b*)

FIG. 26

as to allow the lath to be nailed on in the direction of the risers. In order to obtain a smooth, curved surface on the soffit—which will be more or less warped—care must be taken to aline the blocking by means of a guide lath. In lathing so placed, care should be taken that space is allowed at all points for riveting the plaster, which, under stairways, is subjected at times to jarring that is likely to loosen it unless well keyed or riveted.

NEWEL STAIRWAYS

39. In Fig. 27 is shown a plan of a **quarter-platform open-stringer stairway** with 4-inch square newels framed in the angles, the hand rails making straight connections with the newels, as shown in Fig. 28. The position of the platform beams *a* and *b* and of the floorbeam *c* at the landing,

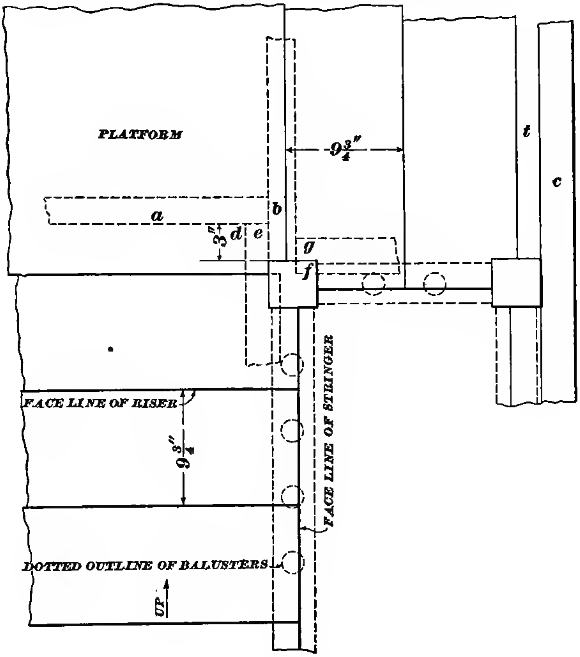


FIG. 27

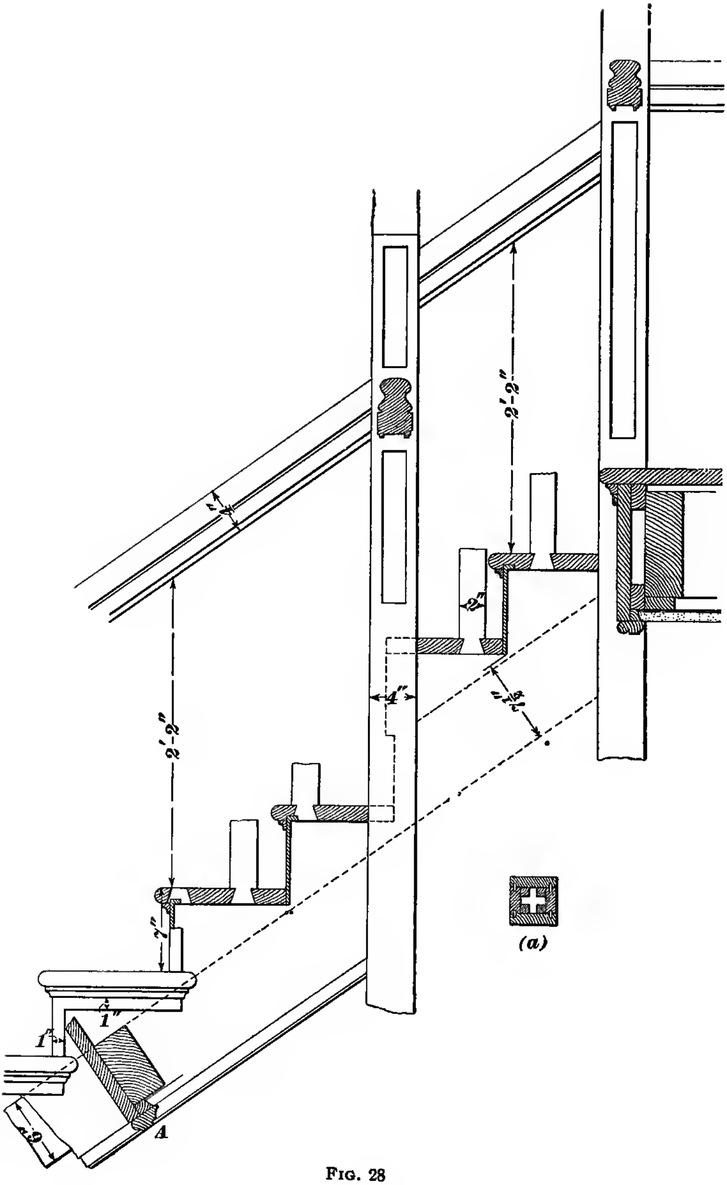
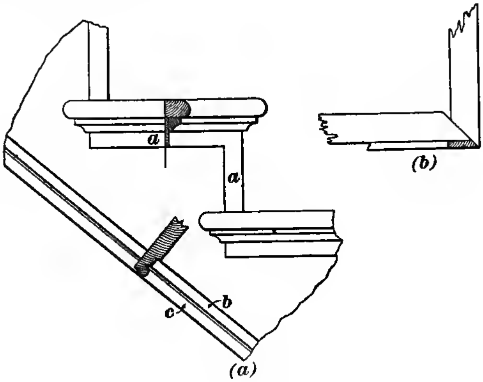


Fig. 28

Fig. 27, should be such that a good bearing is secured for the carriage timbers at *d*, *e* and *f*, *g*. The platform beam *b* should be brought forward to give a support of about $\frac{3}{4}$ inch for the newel.

The elevation, shown in Fig. 28, is projected from the plan, and shows the relative position of the newels, hand rails, balusters, and step trim; the latter is composed of $1'' \times \frac{1}{4}''$ fillets, nosing, and scotia. The newels are built up as shown in Fig. 28 (*a*), slip tongues being inserted into grooves in the sides, and the whole properly glued and blocked. The blocks are first glued to the two narrow sides of the newel, and when dry are planed square with the edge of these pieces. The whole is then heated in a hot box, and the blocks, edges, and slip tongues are glued and brought together with handscrews.



(*a*) (*b*)

FIG. 29

40. Open Stringers.—In Fig. 29 are shown an elevation and a section of an **open stringer**, where fillets are used. At (*a*) is a portion of the stringer showing the step trim with fillets *a*, *a*. The lower portion of the stringer is relieved to form a fascia *b*, and the edge *c* is formed into a quirk bead against which the plaster finishes. While frequently adopted, this method does not give nearly so good a bond for the plaster as does the soffit mold shown at *A*, Fig. 28, in which the edge of the stringer is kept square.

In Fig. 29 (*b*) is illustrated a section of the fillet, mitering with the riser, which shows that the face stringer must be kept back the thickness of the fillet, in order that the latter may miter properly with the riser.

41. Close Stringers.—In Fig. 30 are shown a plan (*a*) and an elevation (*b*) of a quarter-platform stairway with four risers in the flight adjacent to the landing, close-paneled and molded stringers, 6-inch square newels, 2½-inch turned and square-base balusters, and a 4″ × 4½″ double-molded hand rail, having a ramp-and-knee, or goose-neck, connection with the newels. In the plan, *a* and *b* are the principal floorbeams of the platform, and *c* is the top-landing floorbeam. In drawing the elevation, the first step is to locate the treads and risers as shown by the dotted lines. The balusters may be placed at any distance apart that is desirable on close stringers, as their relation to the treads is not noticed. On the plan is shown the relation of the balusters with reference to the newels, from which measurements should be taken.

Observe, in the elevation of the lower newel, that there are two risers at right angles to each other at the center of the newel, one riser extending from the top step of the lower flight to the platform, and the other from the platform to the first step of the short flight, as shown at *d e f*. In this figure, the portion $d h e' h''$ is the elevation, or side view, of the short flight from *d* to *e* on the plan (*a*). A cross-section of the close stringer, illustrating the panel, timbers, blocking, etc., is shown at *D*, and from this the connections with the newels are lined in as indicated. The section *H* along the floor level is the same as at *D*, but should it prove to be too high above the floor at any time, the panels may be reduced in width. Panel work of this character may have stiles at newel connections, and muntins at suitable intervals in the long flights and landing fascias.

42. Half Newels.—In neweled stairways, the rails should always finish against a half newel at the wall connection, and the lower ends of the half newels may be shown below the soffit. Where half newels are placed on the walls

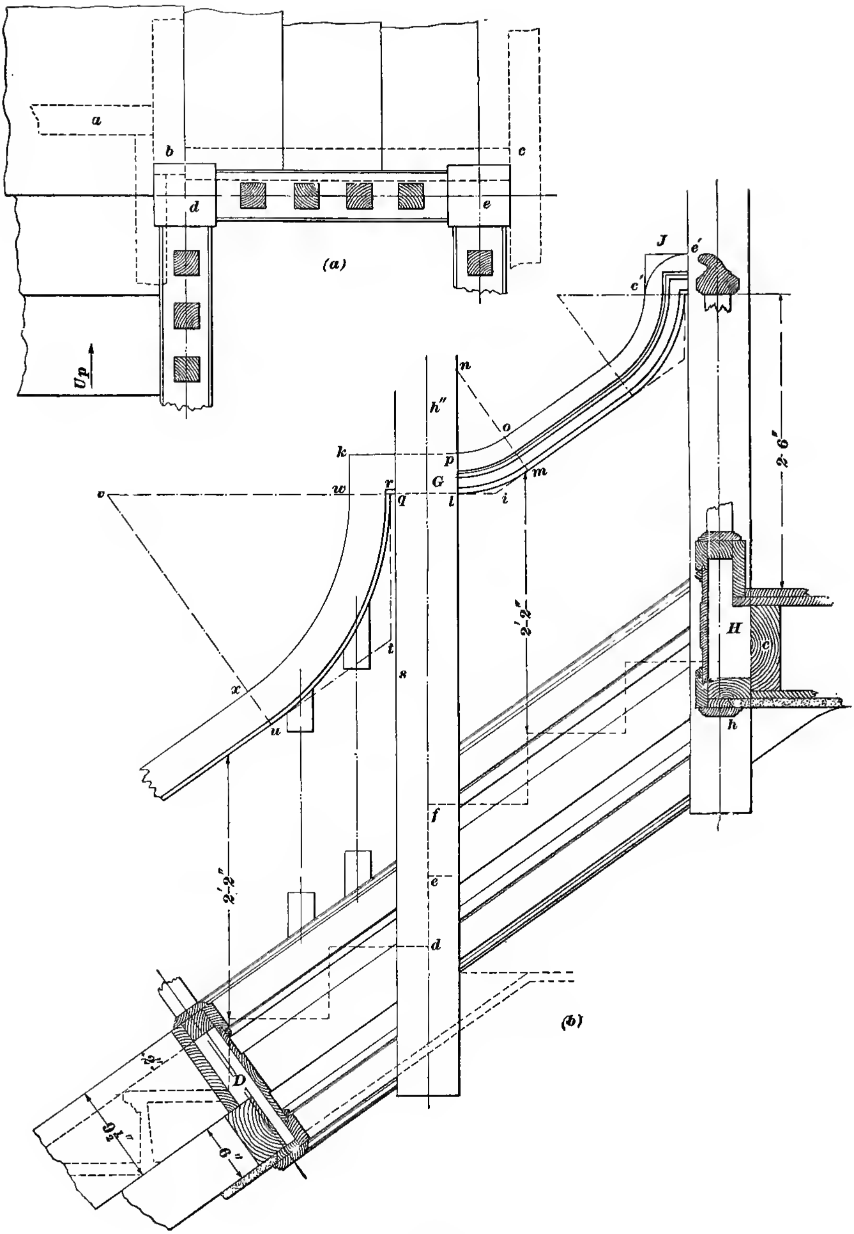


FIG. 30

opposite the platform newels, ornamental flat-arch spandrels may be framed between each newel and half newel, thus finishing the soffit of the platform.

43. Newel Posts and Rails.—The length of newel posts is governed by the depth of the stringer, including the soffit molding. Fixing the height of the easement at *G*, Fig. 30 (*b*), and the height of the level hand rail at *J*, the height of the hand rail up the flight is figured, and the rail is made parallel with the line of the stringer. There is nothing important in the position of *G*, except that it fixes the level of the knee at *k*.

To produce a good easement, draw the horizontal line *l i* at the required height of the easement and continue the bottom line of the inclined rail until it intersects this horizontal line. Lay off *i m* equal to *i l*, and draw *m n* perpendicular to *i m*. Let *m o* equal the thickness of the hand rail; from *n* as a center, describe the easement lines *o p* and *m l*. For the ramp and knee, make *q r* from $\frac{1}{2}$ to $1\frac{1}{2}$ inches; perpendicular to *q s*, draw *r v*, which is a continuation of *i l*. Draw *r t* parallel with the newel, and continue the bottom line of the rail until it intersects *r t*; make *t u* equal to *r t*; from *u* draw *u v* at right angles to *t u*; make *r w* equal to the thickness of the rail; and draw *w k* parallel to *q s*. With *v*, the intersection of *r v* and *u v*, as a center, describe the arcs *r u* and *w x*. The ramp and knee at the upper landing are defined in the same way. The rail may be curved as indicated by the arc $c' e'$, forming a goose neck.

44. Special Arrangement of Newels.—In Figs. 31 and 32 are shown a plan and an elevation, respectively, of a quarter-platform stairway having a quarter-cylinder connection to the landing, thus avoiding the use of a second newel

45. In Fig. 33 are shown a plan (*a*), an elevation (*b*), and a development (*c*) of a straight stairway, with a single newel set diagonally at the landing, the stringer fascia and hand rail being curved to enter two adjacent faces of the newel. In the plan, *a b d c* is the position of the carriage

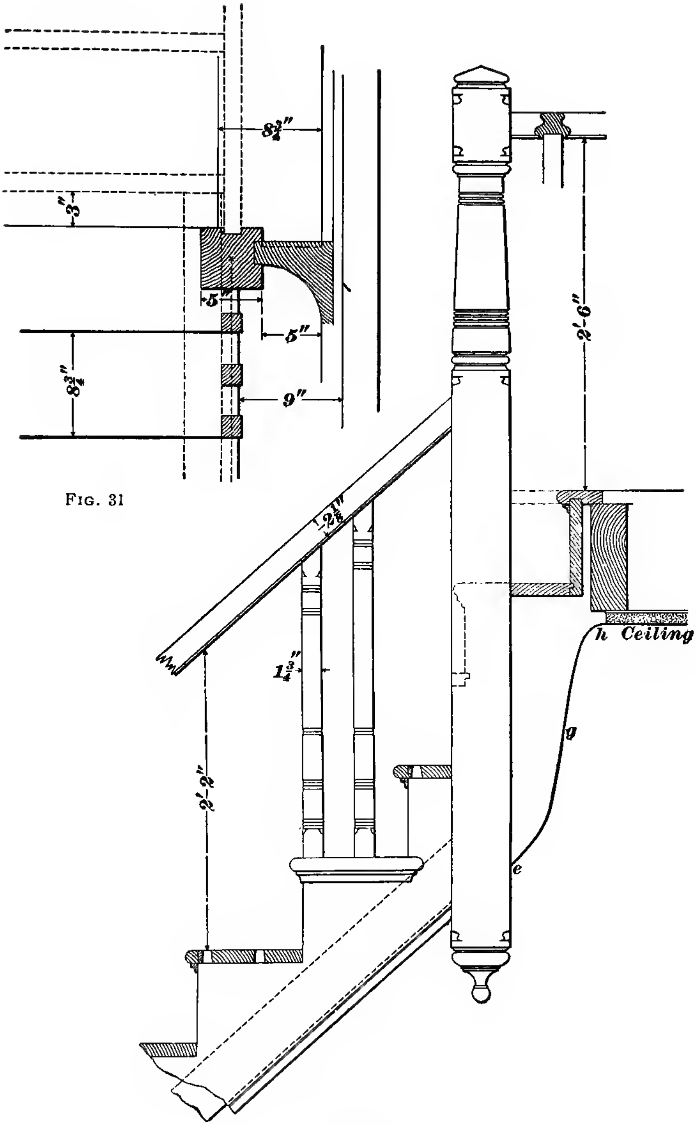


FIG. 31

FIG. 32

timber, and A and B indicate the position of the floorbeams. Half balusters are set against the sides of the newel, to which the hand rails are connected. In the elevation, a', b', d', c' show the depth and position of the carriage timbers, and A is the landing floorbeam.

In the development (c), lay off from the face of the riser $s'e'$ equal to the corresponding distance on the plan, designated at os; then, lay off $e'h'$ equal to the arc sh on the plan;

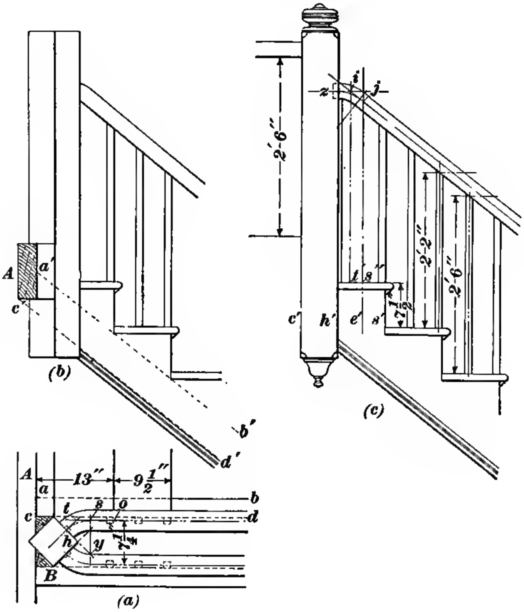


FIG. 33

through h' and c', erect perpendiculars for the sides of the newel; through e', draw $e'j$ parallel with the face of the newel; lay off $s''t'$ equal to st on the plan; parallel with $s''j$, draw $t'i$; from the point where this line intersects the center line of the inclined rail, draw iz parallel with the tread, then jiz is the center line of the rail. This fixes the height of the flight rail at the newel; the level rail is 2 feet 6 inches above the floor. The easement curve at the top of the rail is entirely independent of the horizontal curve on the plan, and may be determined by laying off equal tangents on each side of *i* and erecting perpendiculars to the respective tangents. The point of intersection of these perpendiculars is the center for the easement curve *zj*.

The horizontal curve in the plan is determined by laying off *ts* equal to *th* and drawing perpendiculars *sy* and *hy*. Then, *y* is the center for the curves of the rail and stringer.

46. Swelled Steps and Curved Stringers.—For a pleasing effect, the start of a stairway is often widened by curving the front stringer and increasing the width of several treads by curving the risers. Fig. 34 shows a plan of such a stairway and a development of the stringer and rail. To find the height at which the rail enters the newel, draw the bottom line of the rail through the points where the centers of the short balusters would occur, as at *dd'*; set off from *dd'* the thickness of the rail, 2 inches, and draw the center line of the rail *ef*. The tangents *ck* and *ca* are equal, and *k* is the point where the rail joins the newel. Make *gf* equal to *mk*, draw *co* vertically, and through *o* draw *hj* at right angles to *co*. If the rail is brought to a level on *oj*, its height will be 10 inches above the bottom step *pq*. In this development, the rail is below its real position a distance equal to the height of a short

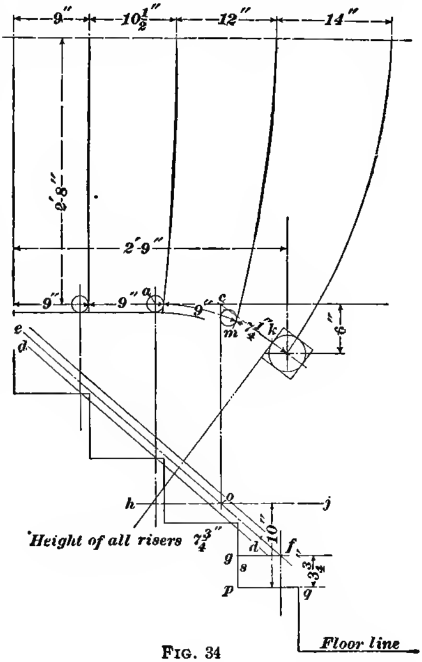


FIG. 34

baluster, or 2 feet 2 inches. This distance added to 10 inches gives 3 feet as the distance from the first step *p q* to the center of the rail at *h j*. If the rail is without an easement to the newel, as at *f*, its height will be 2 feet 5¾ inches.

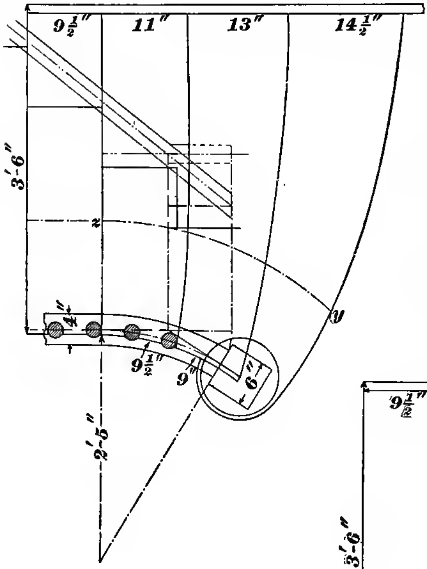


FIG. 35

47. In Fig. 35 is shown a stairway starting at the newel with a curved stringer and swelled steps. The newel in this arrangement is to stand on the first step, the riser extending around to the stringer, which will receive it. Thus, the newel does not project beyond the line of the first step, and, where the space is limited, this method will help to overcome the difficulty. The height of the newel in this case may be determined by the method explained for Fig. 34.

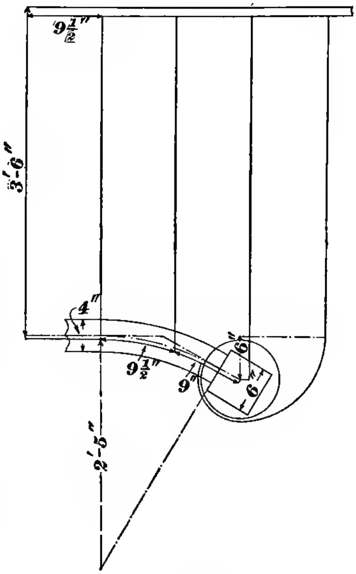


FIG. 36

In Fig. 36 is shown a plan wherein the stringer is curved as in the previous examples, but, with the exception of the starting one, the risers are made straight.

48. Curtail Step.—In Fig. 37 is shown a method of describing the curves of a **curtail step.** Begin by drawing a circle of a size greater than that necessary to enclose the required scroll. Let *a b c d* be such a circle; divide it into sixteen equal parts, and let the diameter of the eye of the scroll be equal to *e f*, in this case 7 inches. The diameter of the eye should always be somewhat greater than the width of the hand rail, which in this case is 6 inches. At right angles to *b d* and tangent to the eye, draw *e′ i*; from *i*, draw *i j* perpendicular to *h g*; and so proceed, drawing lines at right angles to the successive radial lines. This process may be continued to *m* or to any point desired. From the points of intersection *m*, *n*, etc. on the radial lines, with a radius equal to 3 inches, or one-half the width of the rail, describe circles as shown until one is tangent to the eye, as at *x*. From here each successive circle is smaller, so as to be tangent to the eye. Tangent to these circles, draw in an outline of the curve of the hand rail.

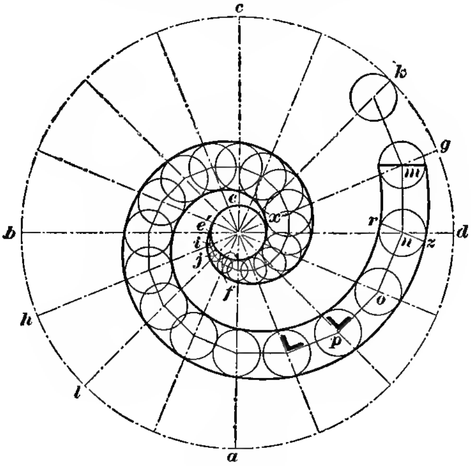


Fig. 37

49. In Fig. 38 (*a*) is shown a plan of the curtail step with curved steps receding from the same. This plan may be drawn from the dimensions given, taking as much of the scroll delineated in Fig. 37 as is required to fulfil the conditions. At zr, Fig. 38 (*a*), is shown the junction of the scroll with the straight rail. Where the scroll has been developed in a diagram, as shown in Fig. 37, the whole or any part of it may be transferred to the plan of the stairway, as was done in Fig. 38.

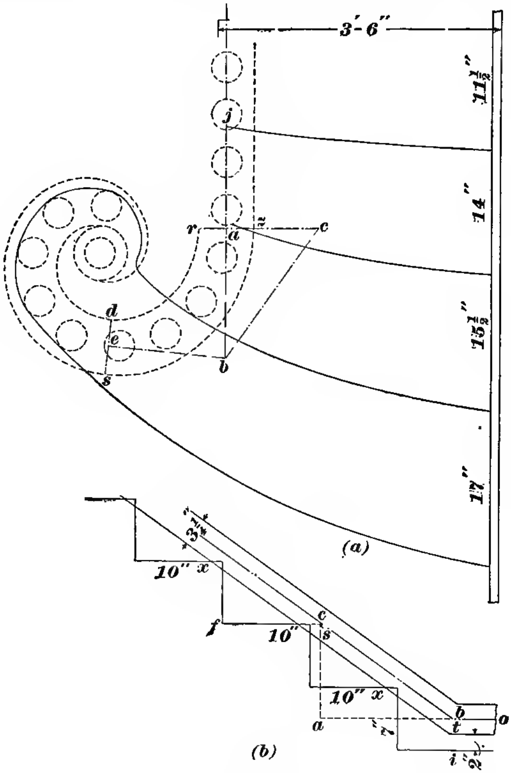


Fig. 38

In order to fix the height of the wreathed portion of the scroll, draw an elevation of the risers and treads as at (*b*). Draw the bottom line of the rail xx through the points on the treads where the center lines of the short balusters intersect; then, draw the center line cb of the rail, and make fs equal to ja in (*a*). Parallel with the riser lines, draw ca

through *s*, and make *t i* equal to, say, 2 inches, thereby fixing the height of the eye and the level portion of the scroll. Make *t b* equal to one-half the depth of the rail, and draw *b a* parallel with the tread line. Then, as the bottom line of the scrolled rail is 2 inches above the first step *i*, and the length of a short baluster is 2 feet 2 inches, the height from *i* to *t* will be 2 feet 4 inches, when the rail is in position. The scrolled rail should be kept as low as that shown, so that its varying and pleasing curvature will be seen to the best advantage.

In the plan, Fig. 38 (*a*), *a b* is the center line of the rail prolonged, and *a c b* is taken from lines similarly lettered in (*b*). From *b*, draw *b e* tangent to the center line of the rail at *e*. The joint *s d* is made at right angles to *e b*. From *s d* to *z r* is the wreathed portion of the rail, since it both curves and rises. The remaining portion of the scroll, from *s d* to the eye, is horizontal, as shown by *b o* in the elevation (*b*), and in this part of the scroll, three or four of the balusters should be bolted at their bases to the step and at their tops to the scrolled rail.

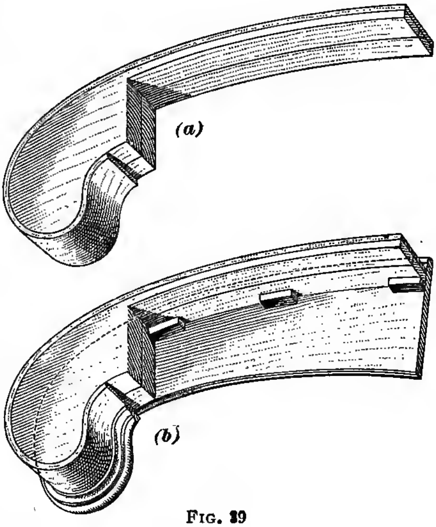


FIG. 39

The construction of the veneered riser and scroll block is shown in Fig. 39 (*a*), and the complete scroll step is shown in (*b*).

SPECIAL FORMS OF STAIRWAYS

50. Quarter-Platform Stairway.—In Fig. 40 is shown a plan of a **quarter-platform stairway** with a quarter cylinder for a continued hand rail. Any radius of cylinder considered desirable may be used, but if the risers *o b* and *o′ b′* are put at a distance equal to one-half the width of a tread from the point *a*—the intersection of the center lines of the rail—the wreath piece will conform to the common pitch of the flights. If the front stringer is a close one, and the risers are placed as shown, the effect will be more agreeable than it would be if the risers were placed either nearer to or farther from the point *a*. This arrangement of the risers will allow a graceful curve in the development of the front stringer and the hand rail, while if placed in any other position, the result will be an unsightly crippled rail and stringer.

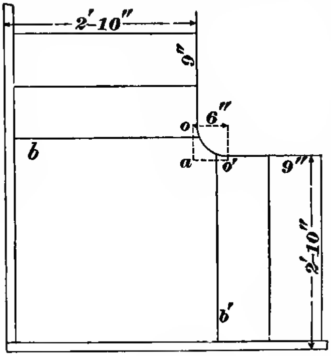


Fig. 40

51. Quarter-Turn Winding Stairway.—The plan of a **quarter-turn winding stairway**, with a quarter cylinder for a continued hand rail and with regular treads above and below, is shown in Fig. 41. It will be noticed that the treads adjoining the cylinder in both flights are reduced. The benefit derived from the reduction will appear in the curve of the rail and the stringer, as it modifies the angle of

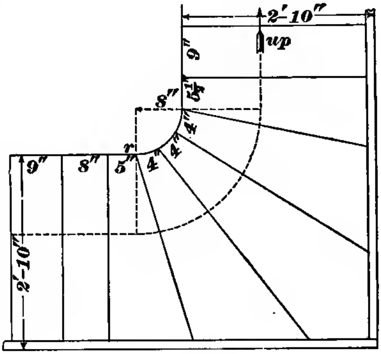


Fig 41

intersection between the pitch of one straight rail and that over the winders, the stringer, of course, being affected in the same manner.

52. Platform and Curved Risers.—In Fig. 42 is shown a plan of a stairway that includes two platforms with a tread and two curved risers in the 10-inch cylinder between the platforms, making a half turn. The wreathed rail over this plan has a pleasing shape, and no ramp is required in the straight rail either above or below the wreath.

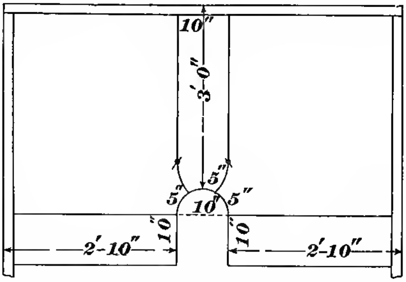


FIG. 42

53. Newel Between Quarter Cylinders.—Fig. 43 shows a plan of a stairway with a newel post set between quarter cylinders on the landing of a flight. The hand rail in this case will be bolted to the newel.

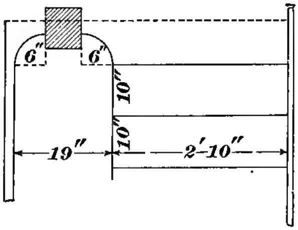


FIG. 43

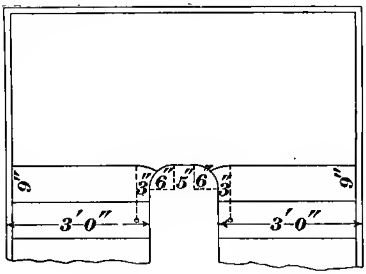


FIG. 44

54. Half-Turn Platform Stairway.—In Fig. 44 is shown a **half-turn platform stairway.** The face of the top riser of lower flight and that of the bottom riser of upper flight have a slight curve adjacent to the flattened cylinder. By this method the whole depth of the cylinder is saved in the width of landing, which is an advantage where space is limited.

55. Winding Stairway.—Fig. 45 shows a plan of a **winding stairway** having seventeen risers. The cylinders for this continued hand rail have a diameter of 10 inches.

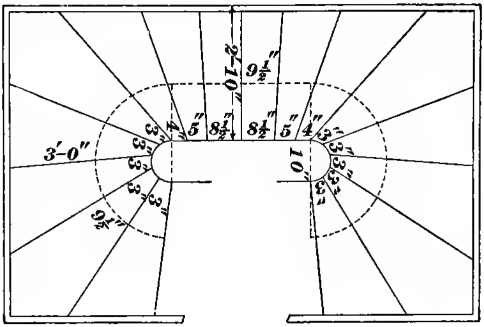


Fig. 45

This arrangement is suitable where space is limited and where the entrance to the staircase is on the side.

56. Arrangement for Intermediate Floor.—Fig. 46 illustrates a plan for the starting and landing of two flights connected by a 12-inch cylinder. Such an arrangement is used where the short flight ascends to an intermediate floor on the platform level.

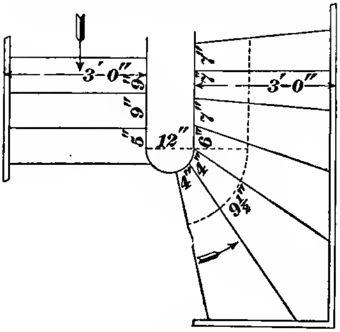


Fig. 46

57. Quarter Platform With Tangent Between Quarter Cylinders.—In Fig. 47 is shown a plan of a quarter-platform stairway for a continued hand rail. The cylinder opening of 18 inches is formed by two quarter circles—each of 5 inches radius—with an 8-inch piece of straight stringer placed between. By this method a platform is secured, and angular winders are dispensed with; the length of the staircase is also reduced.

58. Quarter Platform With Semicircular Cylinder. Fig. 48 differs from the preceding plan only in the form of its cylinder, which is semicircular in plan, and, while requiring a little more run, furnishes a more pleasing rail and cylinder.

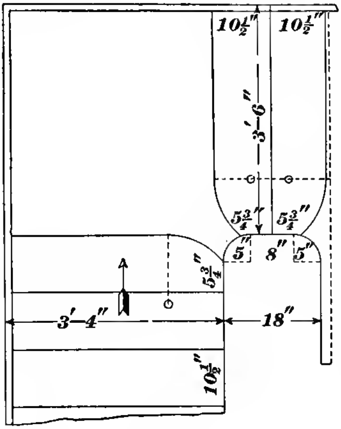


FIG. 47

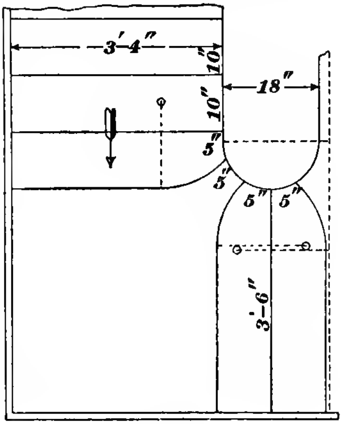


FIG. 48

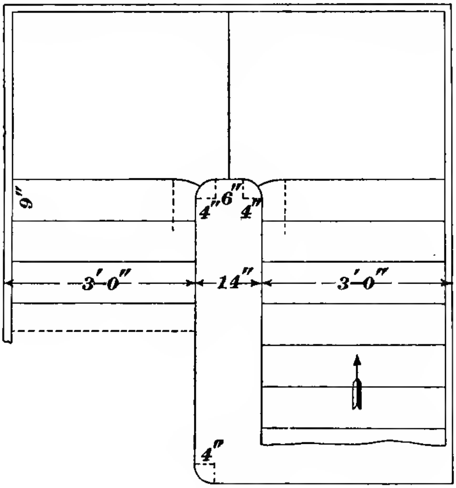


FIG. 49

59. Double Platforms.—Fig. 49 shows a plan of a platform stairway making a half turn, one riser at the center of the cylinder dividing the space into two platforms. Where the run will permit, it is always advisable to dispense with this central riser, thus adding breadth to the platform, and avoiding the danger of stumbling at the step placed where it is not expected.

60. Quarter Platform With Step.—Fig. 50 shows a plan of a quarter-platform stairway with a 15-inch cylinder having a regular step at its center.

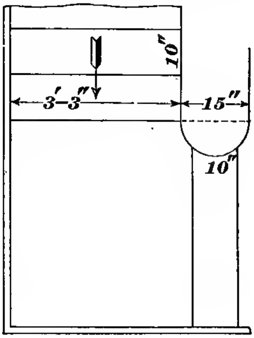


FIG. 50

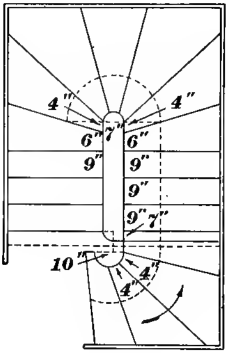


FIG. 51

61. Three-Quarter Turn.—Fig. 51 shows a plan of a winding stairway making a three-quarter turn, the entrance being at one end of the staircase.

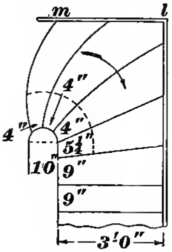


FIG. 52

62. Starting or Landing Winders. Fig. 52 shows a plan of a stairway that has winders either at the starting or at the landing. The curving of the risers is resorted to for the purpose of making them occupy less room from *l* to *m*. Curving the risers in this manner also improves the appearance of the stairway by reducing its angularity.

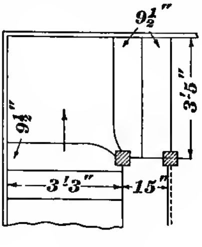


FIG. 53

63. Quarter Platform With Newels.—Fig. 53 shows a plan of a quarter-platform stairway with small newels framed to the stringers in the angles; the hand rail may join the newels either straight, with easements and with ramp and knee, or with a goose neck. The curved risers are introduced to save space in the run of the flights.

64. Platform Stairway With Two Return Flights. In Fig. 54 is shown a plan of a platform stairway with two return, or *wing*, flights, suitable for a public building. The flights and platform may be wainscoted, and, by the introduction of half newels set against the wall opposite the regular newels, a good structural effect is obtained. The regular and wall newels may be carried up as columns and pilasters, further improving the treatment. Flat, ornamental arches may be introduced between the newels and half newels where they extend below the soffit of the platform, to break up and panel the soffit spaces. For a public stairway of this character, in either wood or iron, a better effect is produced by omitting the plaster and showing the framework.

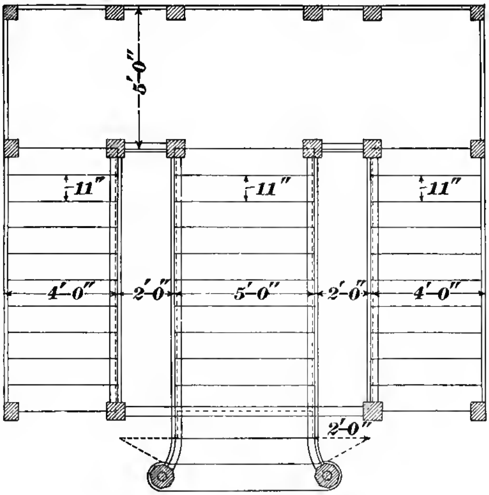


Fig. 54

65. Circular Stairway.—A plan of a **circular stairway** is shown in Fig. 55. All the risers except the three curved ones at the start radiate from the center *b*, and are equally spaced at the front and wall stringers. The front stringer along the first two steps is curved out, to increase the width of the stairway at the start, thus giving it a more pleasing appearance. A curtail step and a hand rail at the starting of such a stairway are very appropriate and attractive. The dotted lines indicate the position of the carriage timbers. A similar method may be followed for elliptic stairways.

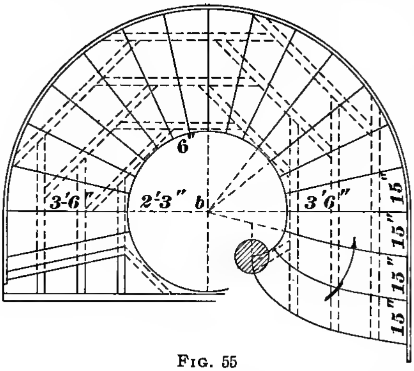


FIG. 55

Instead of a cylindrical front stringer, as in this plan, a circular newel post of sufficient length is sometimes used as a central support, the treads and risers being framed into the central newel and into the wall stringer. The newel post may be cased with $\frac{7}{8}$-inch boards of the same width as the treads at the point of connection, thus affording support and enclosure-like mortises to the steps; the grooves for the risers may also be cut out from the edge of the boards, thereby rigidly securing them. This casing, or staving,

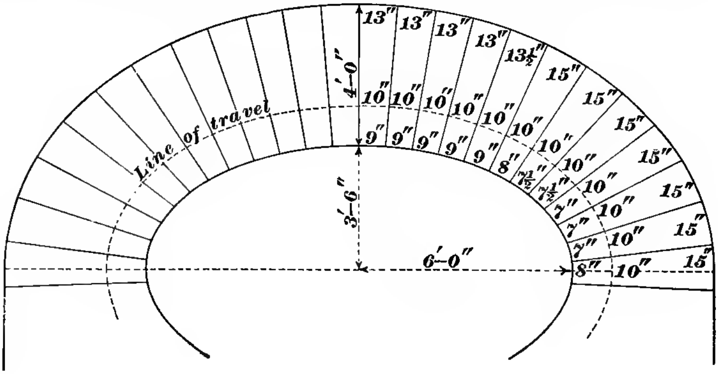


FIG. 56

however, should not be set in place until all the steps are nailed in position.

66. Elliptic Stairway.—In Fig. 56 is shown a plan of an **elliptic stairway.** The customary method of providing a uniform width for the treads along the wall stringer, and also along the front stringer, causes some of the risers to stand at such an angle with the line of travel as to diminish the width of treads at those points. It has the advantage, however, of giving the hand rail a uniform pitch from end to end.

In another method, shown in the plan, the treads are divided equally on the line of travel, and the risers are drawn as nearly as possible normal to the front stringer.

WAINSCOTING

67. The paneled wall lining for halls and stairways is made of different heights, the arrangement and treatment of the panels being varied to meet the ideas of the designer. In Fig. 57 is shown a portion of wainscoting as it passes from the hall up the flight. A vertical section of the framework, panels, and moldings as usually made is shown at *D*, where *a* is the baseboard; *b*, the bottom rail; *c*, the panels; *d*, the middle rail; *e*, the top rail; *f*, the cap molding; *g*, the base molding; and *h*, the furring strip. In the elevation, *h' h'* is a stile with a groove *j* to receive the return wainscoting; at *k*, *k* are muntins. The stile *h' h'* extends the whole height, and the three rails are framed into it. The panels are square on the level portion, but up the flight they change their shape and become narrower, as the width of the wainscot *n n* is less than the width *m m*.

The curves at the junction of the pitch and level lines are described from three different centers, as shown. The curves cannot be described from a common center, as the two portions are not of the same width. By producing the tangents of the level and inclined portions of the top, bottom, and central rails, and deciding on the length of the curves, radial

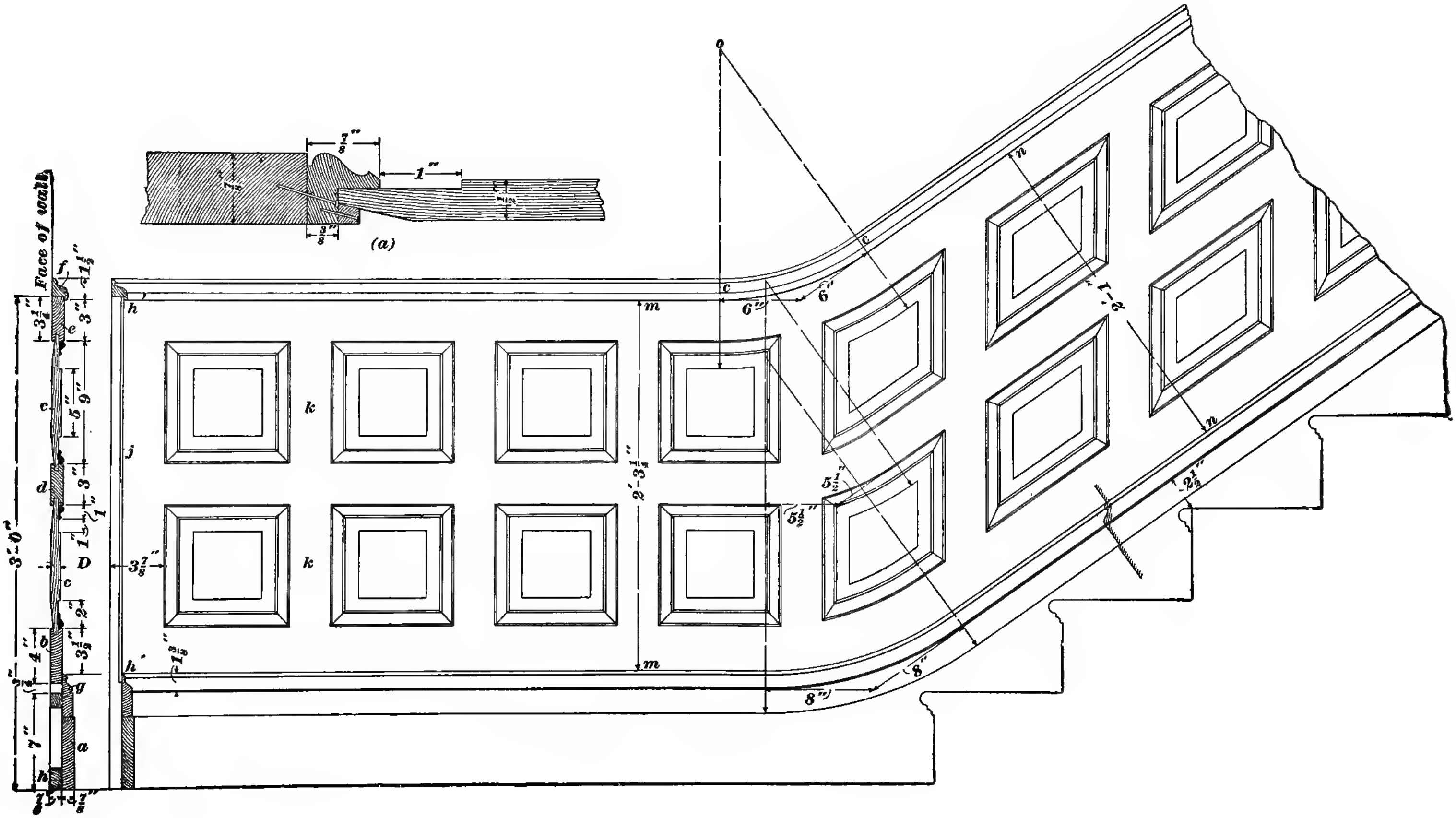

Face of wall
3'-0"
3¼"
4"
7"
1½"
3"
9"
5"
3"
1"
1"
2"
3½"
7/8"
a
b
c
d
e
f
g
h
D
(a)
7/8"
1"
3/8"
h
j
k
m
c
o
n
6"
5½"
8"
2'-3¼"
2'-1"
3⅞"
1⅜"
2½"

FIG. 57

lines may be drawn from the points, as at *c*, *c*, thus locating the center, from which simple curves may be drawn.

At (*a*) is shown a method of fastening the panels so that no nails will show on the face of the molding. The panels are polished separately and put in place after the frame and moldings are finished. The framework should be well seasoned, and the walls should be perfectly dry before the wainscoting is set in position.

ROOFING

(PART 1)

INTRODUCTION

1. Definitions.—The **roof** is the upper external part of a building that covers it in from the sky; the term includes the roof construction and the roofing. *Roof construction* is discussed in another Section. **Roofing** is the outer covering that is applied to the surfaces of the roof to protect the building from the effects of the weather, and is supported by the roof construction.

Many kinds of materials are used for roofing, among which are iron, tin, copper, zinc, wood, slate, cement, tile, tar, asphalt, asbestos, felt, paper, and canvas. The methods and materials used in roofing will be described in this Section.

2. Classification of Roofings.—Roofings may be classed as tight or open.

Tight roofing is a roofing in the form of an impenetrable layer of materials, which must be free from openings through which water can find its way. These roofings are formed of sheet metal, or of felts or canvas impregnated with waterproofing materials. Tight roofings must be used on all roofs that are flat, or nearly so. A roof having a pitch of 30 degrees or less should be covered by a tight roofing.

An *open roofing* is one that will shed water if placed on a roof having a pitch of 30 degrees or more, but which contains joints, crevices, or holes through which water could easily pass, if these roofings were placed on a flat roof. Examples

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TABLE I

APPROXIMATE WEIGHTS OF ROOFING, AND MINIMUM AND MAXIMUM PITCHES ADVISABLE

Roofing	Weight per Square of 100 Feet Pounds	Minimum Rise per Foot Inches	Maximum Rise per Foot Inches
5-ply composition, pitch and gravel on boards	630 to 680	$\frac{3}{8}$	3
5-ply composition, pitch and slag on boards	530 to 630	$\frac{3}{8}$	3
5-ply composition, pitch and gravel on concrete	650 to 700	$\frac{3}{8}$	3
5-ply composition, pitch and slag on concrete	550 to 600	$\frac{3}{8}$	3
4-ply composition, pitch and gravel on concrete	590 to 640	$\frac{3}{8}$	3
4-ply composition, pitch and slag on concrete	490 to 540	$\frac{3}{8}$	3
4-ply composition, asphalt and gravel on boards	630 to 680	$\frac{3}{8}$	6
4-ply composition, asphalt and slag on boards	530 to 580	$\frac{3}{8}$	6
4-ply composition, asphalt and gravel on concrete	640 to 690	$\frac{3}{8}$	6
4-ply composition, asphalt and slag on concrete	540 to 590	$\frac{3}{8}$	6
4-ply composition asphalt, no gravel or slag on boards	150 to 160	$\frac{3}{8}$	6
4-ply composition over concrete, using asphalt, no slag or gravel	160 to 170	$\frac{3}{8}$	6
3-ply ready roofing, no surfacing	55 to 60	3	
4-ply ready roofing, no surfacing	90 to 95	3	
3-ply ready roofing, slate surface	90 to 115	3	
4-ply ready roofing, slate surface	120 to 130	3	
$\frac{3}{16}$-inch slate on 3-ply composition	375 to 400	$\frac{1}{4}$	3
1-inch promenade tile on 3-ply composition	1,200 to 1,300	$\frac{1}{4}$	3
Canvas	20 to 25	$\frac{1}{4}$	
Roll roofing, No. 26 iron or steel, galvanized	102 to 108	2	
Roll roofing, No. 26 iron or steel, painted	86 to 91	2	
Pressed standing-seam, No. 26, iron, galvanized	100 to 105	3	
Pressed standing-seam, No. 26, iron, painted	86 to 90	3	
Corrugated iron or steel, No. 26 galvanized	98 to 102	3	
Corrugated iron or steel, No. 20 galvanized	175 to 185	3	
Corrugated iron or steel, No. 26, plain	85 to 90	3	
Corrugated iron or steel, No. 20, plain	165 to 175	3	
Corrugated asbestos covered sheets, No. 20 iron	230 to 285	3	
Tin, flat-seam	70 to 110	2	
Tin, standing-seam	75 to 115	2	
Tin, ribbed	85 to 135	2	
Copper, 16-ounce, standing-seam or ribbed	120 to 125	2	
Wood shingles, 4 inches to weather	200 to 250	6	
Metal shingles, slates, and tiles	75 to 125	4	
Asphalt shingles	200 to 265	4	
Slate, $\frac{3}{16}$-inch	640 to 750	4	
Slate, $\frac{1}{4}$-inch	860 to 1,000	4	
Asbestos shingles, American method	450 to 650	4	
Asbestos shingles, diagonal or hexagonal methods	300 to 325	6	
Clay tiles	700 to 1,900	4	
Cement tiles	1,200 to 1,350	4	

of such roofings are wooden shingles, slate, tile, and corrugated metal.

3. **Unit of Measurement of Roofing.**—The customary unit used in measuring roofing is a **square,** which is a quantity of roofing sufficient to cover 100 square feet. Where a square of roofing is mentioned, it will be understood that this area is meant.

4. **Weights of Various Roofings.**—In Table I are given the approximate weights of some of the principal roofing materials, as applied to roofs. The weights are approximate, as there is a variation not only in weight of similar products made by different manufacturers, but also in the methods of laying roofings.

5. **Pitch Required for Roofing Materials.**—In Table I is also given the minimum pitch which it is advisable to use with the roofing materials mentioned. The maximum pitch at which certain forms of roofing should be laid is also here tabulated.

6. **Flashings.**—Water is apt to enter the roof at the joints or angles between different roof surfaces, and between roof surfaces and other surfaces against which the roofing stops. To prevent this, *flashings* are used. Flashings consist of pieces, or strips, of sheet metal or other impervious materials that are used to cover the joints in the roofing. The best flashings for each particular form of roofing, together with its method of application, will be described in connection with the description of that form of roofing.

KINDS OF ROOFING

COMPOSITION ROOFING

NATURE AND USE

7. Definitions.—*Composition* roofing is a form of tight roofing composed of several thicknesses, or layers, of felt cemented together by means of asphalt or coal-tar pitch, and generally covered with a layer of gravel or crushed slag.

When the layers of felt are cemented together in their final position on the roof, the roofing is described as *built-up roofing*. When similar materials are cemented together at a factory, and brought to the building in rolls, the roofing is known as *prepared*, or *ready, roofing*.

When coal-tar pitch is used as the cementing material in built-up roofing, a top coat of slag or gravel is generally applied. When slag is used, the roofing is called *slag roofing, pitch-and-slag roofing*, or *tar-and-slag roofing*. If gravel is used, the roofing is known as *gravel roofing, pitch-and-gravel roofing*, or *tar-and-gravel roofing*.

In case asphalt is employed as the cementing material, gravel and slag are not always used as a final coating. Roofings in which asphalt is used are known as *asphalt roofing*, and when covered with slag, as *asphalt-and-slag roofing*, etc.

8. Pitch of Composition Roofs.—Composition roofing is adaptable for roofs having a pitch of 3 inches or less to the foot, although by using a pitch or asphalt having a higher melting point than the materials used for a low-pitched roof, this roofing may be used on steeper surfaces.

MATERIALS USED IN COMPOSITION ROOFING

9. The materials used in composition roofing are felt, building paper, coal-tar pitch, asphalt, slag, gravel, and crushed stone.

Felt.—The felt used for composition roofing is an absorbent fabric composed of fibers, such as wool, hair, asbestos, or cotton. It is made in strips 32 inches wide, and the thickness commonly used, known as *single-ply,* is supplied in rolls containing 400 square feet. Felt may be *unsaturated* or *saturated* with either tar or asphalt. The unsaturated felt weighs about 5 pounds to the square of roofing, and the saturated felt weighs from 12 to 20 pounds to the square. Saturated felts are known as *tarred felts* or *asphalt-saturated felts,* according to the saturating material used. A single thickness is called a *single-ply felt.* When two or more thicknesses are cemented together, the product is known as *two-ply felt, three-ply felt,* etc.

Building or Sheathing Paper.—Building or sheathing papers, used to some extent in certain forms of roofing, are made by the same process as felts, but are of harder stock, and are not well adapted for saturation by tar, pitch, or asphalt. These papers are supplied in rolls 36 inches in width.

Pitch or Tar.—Pitch or tar used for roofing is made by distilling selected coal-tars mixed in such proportions that the product will have a melting point adaptable to the conditions under which it is to be used.

Asphalt.—Asphalt, or bitumen, is a natural mineral product. The principal supply comes from the great asphalt lakes of Trinidad. Asphalt is not liable to injury from ordinary heat or cold, is impervious to water, and is unaffected by acids.

Slag.—The slag used for roofing purposes is blast-furnace slag crushed, washed, and screened to sizes from $\frac{1}{4}$ to $\frac{5}{8}$ inch.

Gravel.—Gravel for covering roof surfaces should be washed and graded so that less than 10 per cent. is smaller than $\frac{1}{4}$ inch in size, and less than 10 per cent. is over $\frac{5}{8}$ inch in size.

Crushed Stone.—Crushed stone graded as described for gravel is sometimes used in place of gravel.

LAYING COMPOSITION ROOFING

10. The following methods of laying the various forms of composition roofings are typical of those that have proved satisfactory in actual use. These, as well as other equally satisfactory methods, are recommended by the manufacturers of the materials used. The manufacturers issue detailed directions for the proper use of their materials, and these directions should be carefully followed in laying composition roofs.

11. Laying Composition Roofing on Boards, Using Pitch.—A composition roofing of the first quality, laid on roof boarding, is shown in Fig. 1. Work is begun at the lower edge, and over the boarding *a* is laid a single thickness of unsaturated felt or sheathing paper *b*, each sheet lapping about 2 inches over the lower one as at *c*. This layer is nailed as may be necessary to hold it in place until the upper layers of felt *d* are laid.

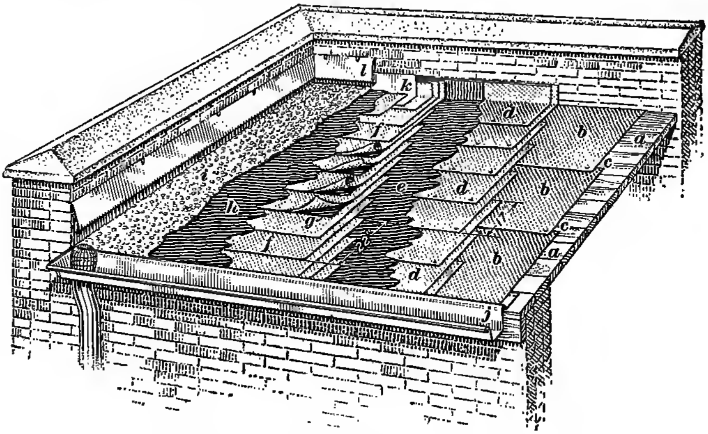


Fig. 1

The sheathing paper *b* is covered with two layers of saturated felt *d*, the upper sheet lapping over the lower one 17 inches. These layers are not cemented together, but are nailed in place. The surface is then coated uniformly with hot pitch as shown at *e*. Over this coating of pitch three plies, or thicknesses, of saturated felt *f* are laid, each sheet lapping 22 inches over the one below. The layers are cemented together with hot pitch as shown at *g*. The surface of the three layers is then coated with hot pitch *h*, in which is embedded a layer of slag or gravel *i*.

At *j* is a form of hanging gutter which extends under the roofing. The gutter has a lip which projects above the surface of the roof boarding *a* so as to prevent the pitch and gravel from running into the gutter in excessively hot weather.

At *k* is shown a sheet-metal flashing which is built into the roofing and extends up on the wall 4 or 5 inches. This flashing is called a *base flashing*. Another flashing, known as a *cap flashing*, or *counterflashing*, is shown at *l*. This flashing extends into the brick wall, and down over the base flashing as shown.

12. This roof when completed forms a homogeneous mass consisting of five layers of saturated felt and two layers of pitch. The pitch in hot weather is apt to soften and soak through the felt, thus uniting the five layers into one. The building paper *b* prevents the pitch from dripping through crevices in the roof boarding. The first coatings of pitch are applied with a mop and the top coating is poured over the felt from a dipper. The slag or gravel is shoveled into this melted pitch, and is distributed evenly over the surface with a stiff broom.

The object of putting slag or gravel on a roof is to protect the pitch and felt from the effects of the weather, and from fire. A properly made roof, consisting of five plies of saturated felt covered with slag or gravel, such as described, will last for 20 years or more. Some roofing companies guarantee roofs made in the manner just described for 20 years.

13. Quantities of Materials Required.—A square of roofing laid as just described will require one layer of sheathing paper, weighing 5 pounds; five plies of saturated felt, weighing about 75 pounds; 150 to 200 pounds of pitch; and 300 pounds of slag or 400 pounds of gravel. The total weight for a square of roofing covered with slag will be from 530 to

580 pounds. The weight of a square of roofing covered with gravel will be from 630 to 680 pounds.

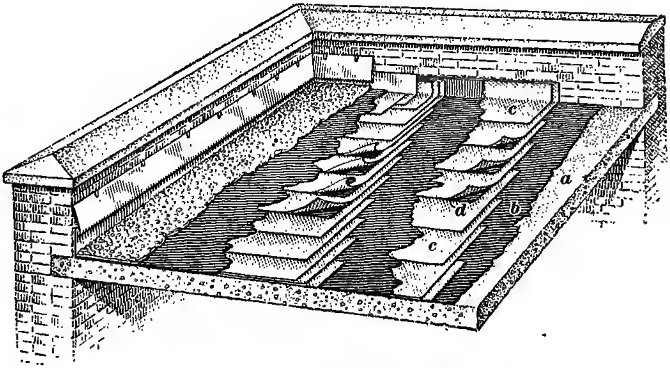


Fig. 2

By omitting one of the upper layers of saturated felt a four-ply roofing is formed. This roofing is of good quality, and is cheaper to lay, but will not last as long as a five-ply roofing.

14. Laying Composition Roofing Over Concrete, Using Pitch.—When a composition roofing with pitch is laid over a concrete surface, the construction will be as illustrated in Fig. 2. The concrete surface *a* is coated with pitch *b*. This serves to hold the first layers of felt in place, as nails cannot be driven into the concrete. Over this coating are laid two plies of felt *c*, saturated with pitch. The upper ply is lapped 17 inches over the lower ply, and they are cemented together with hot pitch *d*. The remainder of the roof is then laid in

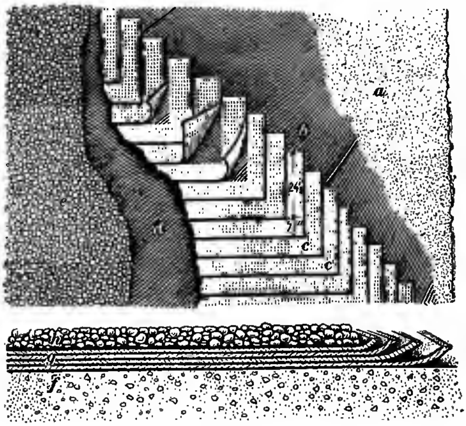


Fig. 3

the same manner as already described for pitch roofing over boarding. This method forms a five-ply roof, and requires more pitch than the same roofing over boarding.

15. Four-Ply Composition Roofing Over Concrete, Using Pitch.—Another excellent method of laying a roofing on concrete is shown in Fig. 3. It consists in coating the concrete *a* with hot pitch *b*, and laying four plies of saturated felt *c*. Each sheet laps 24½ inches over the preceding one, and is mopped the full 24½ inches with hot pitch, so that the sheets of felt do not come in contact with each other. Over the four layers so applied, hot pitch *d* is poured from a dipper, and slag or gravel *e* is embedded in the pitch. Below the plan is shown a section through this roof in which *f* represents concrete, *g* the four layers of felt, and *h* the slag or gravel.

The method just described is also used with three plies of felt instead of four plies, for a cheaper form of roofing. In this case the felt is lapped 22 inches. Such a roofing will not last so long as a four-ply roofing, and will naturally cost less.

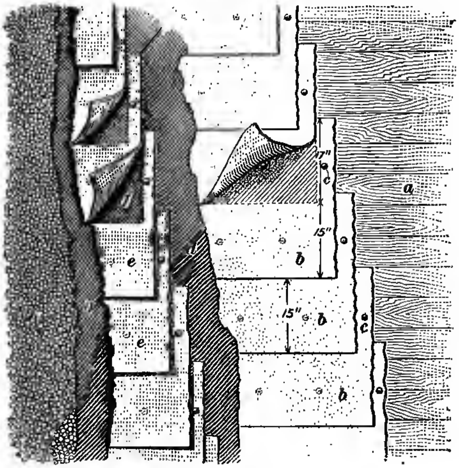


FIG. 4

16. Composition Roofing Over Boards, Using Asphalt.—A standard method of laying a built-up roofing with asphalt as the cementing material is illustrated in Fig. 4. Over the roof boarding *a* is laid two-ply felt *b*, each sheet lapping 17 inches over the preceding one, thus making two thicknesses. This two-ply felt consists of one ply of asphalt-saturated felt and one ply of heavy unsaturated paper, the two plies being cemented together with asphalt. The unsaturated side is laid against the boarding. The sheets are secured to the roof boards with three-penny barbed roofing nails *c* driven through flat tin disks, spaced 10 or 12 inches apart, and placed about 10 inches below the top edge of the sheet.

The top surface of these sheets is then mopped with hot asphalt *d*, and two thicknesses of asphalt-saturated felt *e* are laid in the asphalt. Each sheet is lapped 17 inches over the preceding one, and is nailed in the same manner as the first sheets. Each sheet is mopped with hot asphalt *f* before the succeeding sheet is lapped over it. On top of the felt an even coating of hot asphalt *g* is spread, and covered with a layer of crushed slag or gravel *h*.

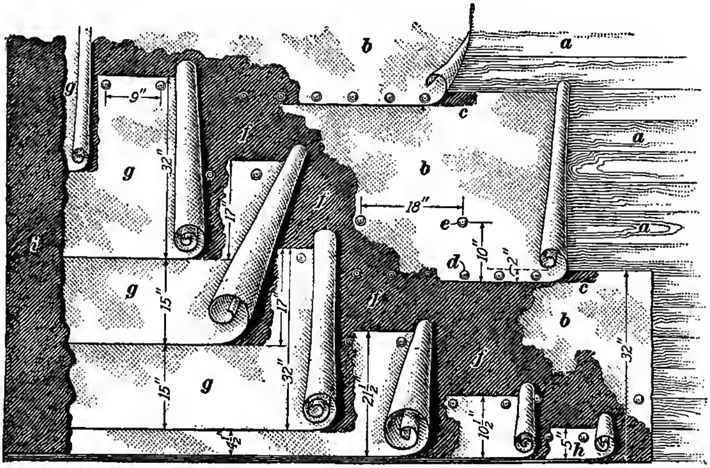


Fig. 5

17. Asphalt Roofing Without Gravel or Slag. Another method of building up an asphalt roofing is shown in Fig. 5. In this method the roof boarding *a* is covered with one thickness of two-ply felt *b*. This felt is composed of two plies of felt cemented together by means of asphalt. One ply is saturated with asphalt, and the other is unsaturated. The unsaturated side is placed against the boarding. The second sheet is lapped over the first sheet 2 inches, and the sheets are cemented together with asphalt as at *c*. Nails *d* are driven every 6 inches along this lap, and also along the middle of the sheet, as at *e*, nails being driven through flat tin disks about 18 inches apart.

18. On this surface hot asphalt *f*, Fig. 5, is applied, and two layers of saturated felt *g* are laid. The first strip of felt *h* is called an *edging strip*. Hot asphalt is mopped on the paper *b* and the edging strip is laid and nailed as shown. Over this 10½ inches is mopped with asphalt and the 10½-inch strip is laid. Over this a 21½-inch space is mopped, and the 21½-inch strip of felt is laid. Each succeeding sheet extends down 17 inches on the preceding sheet, and 15 inches above it. This space is mopped with hot asphalt, and the sheet is laid in place and nailed. This process will be readily understood by a study of the figure.

Over this felt an even thickness of asphalt *i* is spread, so as to provide a neat, even appearance to the roofing. No slag or gravel is used in this method. It is claimed that when asphalt is used, slag or gravel is superfluous. The asphalt is not subject to the same deterioration as coal-tar pitch. It is also not so inflammable as pitch, and therefore protects the roof from fire.

A similar three-ply roofing can be made by using one thickness of saturated felt for the last layer. In this case the upper sheets would be laid with a 2-inch lap instead of 17-inch lap. This roofing will naturally be less durable than the four-ply roofing, but is cheaper to install.

19. Asphalt Roofing Over Concrete.—When asphalt roofing is to be applied to a concrete surface, as in Fig. 6, a special priming coat *a* is first applied to the concrete *b*, to furnish a bond between the concrete and the asphalt *c*. After this has dried, three plies of saturated felt *d* are applied as shown in the figure. Each ply is laid in a coating of hot asphalt, which holds the felt to the roof. Nails cannot be used, as they cannot be driven into the concrete. Over the felt an asphalt coating *e* is applied, and forms a finish for the roof. This roofing weighs from 135 to 145 pounds to the square.

If slag or gravel is applied, a coat of hot asphalt is distributed evenly over the roof, and on this coat the slag or gravel is spread to form an even and finished surface.

20. Inspecting Composition Roofing.—Composition roofing may be inspected by cutting a test strip for every 25 squares of roofing. These strips are 3 inches wide and not less than 3 feet long. They are cut across the strips of felt as laid, so as to expose a complete section of the roofing. As these cuts are made at random, they show average conditions. The tests are made before the slag or gravel is applied, and the strips are replaced after inspection, the roofing being patched by covering the spots tested with as many plies of felt and pitch or asphalt as were used in the original roofing.

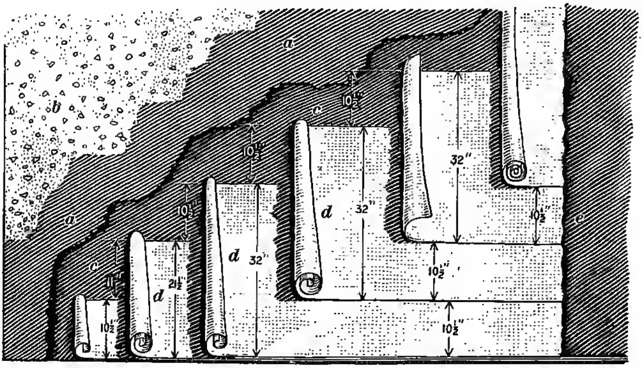


Fig. 6

21. Slate or Tile Surfaces on Composition Roofing. When it is desired to use the roof for storage, walks, or similar purposes, it is necessary to provide a surface that will not be damaged by such use. This may be done by using small squares of slate, or tiles, known as *promenade tiles.* These materials are used in place of the slag or gravel on pitch roofing, or are placed on top of the asphalt top coating on asphalt roofing.

The slates used for roof surfaces are usually $\frac{3}{16}$ or $\frac{3}{8}$ inch thick, and vary in size from 3 inches by 6 inches to 6 inches by 12 inches. The edges may be left rough as cut, or, in the thicker sizes, may be sawed with square edges. The slates are bedded in hot pitch or asphalt, and may be laid in any of the patterns indicated in Fig. 7 (*a*), (*b*), (*c*), and (*d*).

The slates just mentioned are laid one at a time in the hot asphalt. Slates for the same purpose are also made in units consisting of five pieces of slate, each 3 inches by 6 inches, and mounted on a backing of roofing felt. These units are applied by embedding them in a coating of hot asphalt in the same manner as the single units.

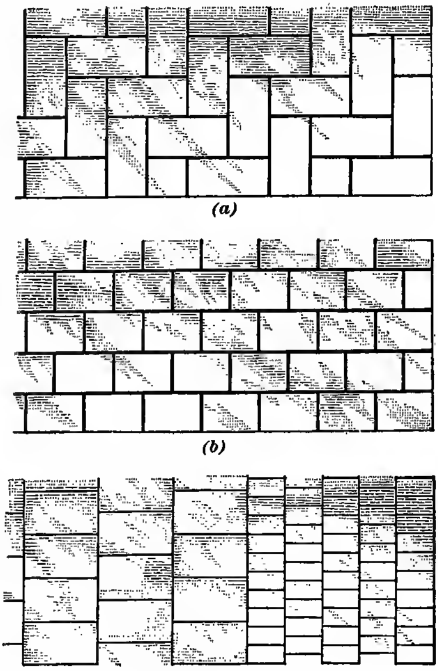

(*a*) (*b*) (*c*) (*d*)

FIG. 7

22. Promenade tiles are made of burned shale, and are usually 6 inches by 9 inches by 1 inch in size, although they are made in many other shapes and sizes. They may be laid in a variety of patterns, such as those shown in Fig. 7.

The standard colors of promenade tiles are red and brown, although other colors may be obtained by glazing. As the glazing is entirely on the surface, and may be worn off by usage, glazed tiles are not so satisfactory as tiles in which the wearing surface is of the same composition as the body of the tile.

Promenade tiles for roofs are laid on a 1½-inch bed of cement mortar spread over a water-tight composition roofing. This mortar is mixed with very little water, so as to form a hard solid mass when tamped. The tiles are soaked in water for at least $\frac{1}{2}$ hour before laying. The joints between the tiles should be $\frac{1}{2}$ inch wide and filled with cement mortar composed of 1 part cement and 2 parts sand.

23. Flashings for Composition Roofings.—Composition roofings are flashed against the vertical surfaces of walls, chimneys, and bulkheads, by extending the roofing up on the vertical surfaces about 6 inches, as at *a* in Fig. 8. This turned-up portion is covered with a metal counterflashing *b*. The counterflashing is let into a joint *c* in the brickwork at least 1 inch, and is held in the joint by wall hooks *d*. The joint is then filled with elastic cement *e*. A triangular cant strip *f* is sometimes nailed in the corners to make a gradual bend so that the felt will not crack.

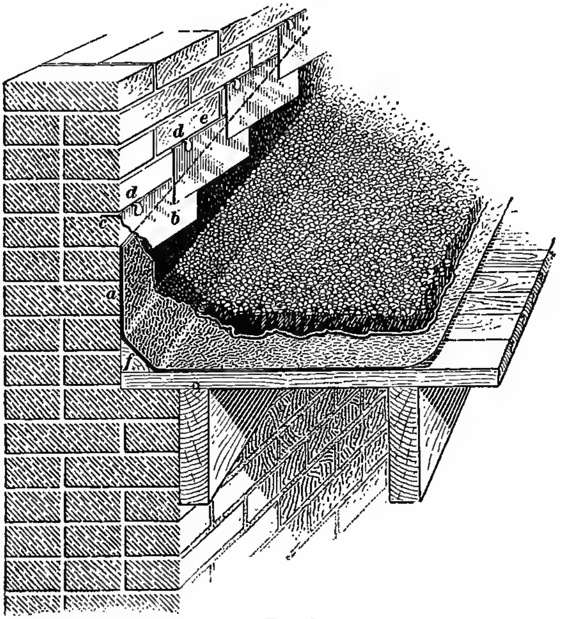


Fig. 8

24. A better method of flashing against walls is shown in Fig. 9, in which the roofing felt *a* extends up on the wall about 5 inches. Extending down over the turned-up portion is the base flashing *b,* which may be of metal or of a composition similar to the roofing. This flashing extends out on the roofing at least 4 inches, up against the wall at least 8 inches, and is secured to the roof surface only, so that it will not be torn if there is any settlement in the roof construction. A strip of felt *c* is cemented to the roof over the flashing, to cover the heads of the nails. A sheet-metal counterflashing *d* is placed over the flashing *b* and is held in place by the flashing hooks *e.*

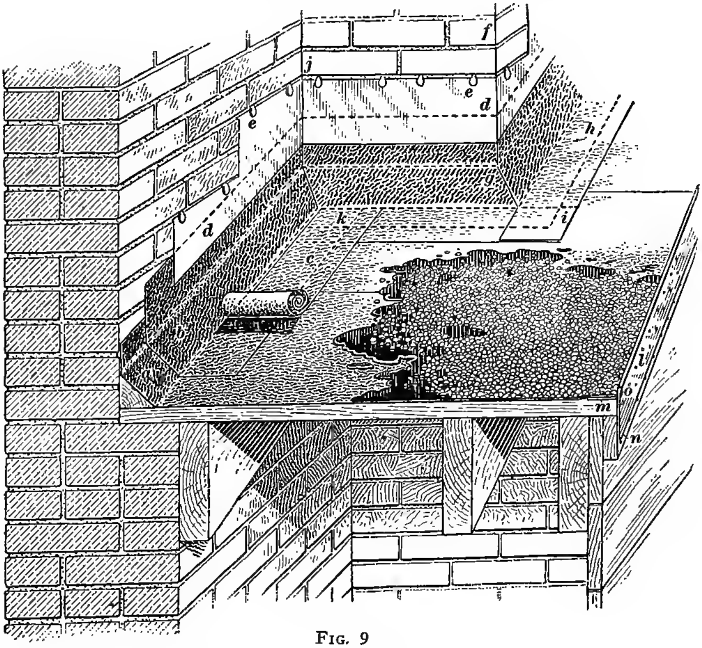


FIG. 9

In some cases, as in Fig. 10, the base flashing *a* is set in position after two of the sheets of felt *b* are in place, and the remaining layers *c* are put on above the flashings. The flashing is then covered with the counterflashing *d,* which is held in place by the flashing hooks *e.* The slag or gravel surface, if used, is applied after the flashing is in place.

25. In Fig. 11 is shown a form of *raggle block a,* by means of which the roofing *b,* as well as the counterflashing *c,* may be built securely into the wall. These raggle blocks are made of terra cotta so as to fit in with the brickwork. A groove, or raggle, *d* is formed in the blocks to receive the flashing. The roofing is cut off at a length sufficient to enter the raggle, and is covered by the cap flashing. The roofing and flashing are then firmly wedged and cemented into the raggle. The overhanging drip *e* assists in turning the water away from the joint. These raggle blocks are made in a variety of styles and are built into the wall by the mason at the proper height to receive the roofing and the flashing.

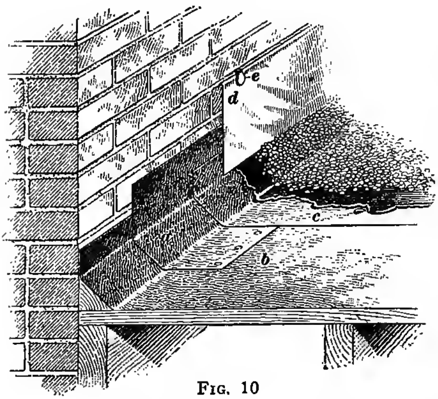


Fig. 10

26. Cap flashings as well as base flashings are sometimes made of felt and cementing material. The application of one form of this kind of flashing is shown in Fig. 12. The roofing *a* is carried up to the top of the cant strip *b*. A raggle block *c* is built into the wall at the proper height to take the cap flashing *d*, which is built up of several layers, usually three, of single-ply felt. These layers are separately inserted in the raggle *e* and are cemented together and to the roofing felt *a*. This method may also be used with roofing over a concrete base.

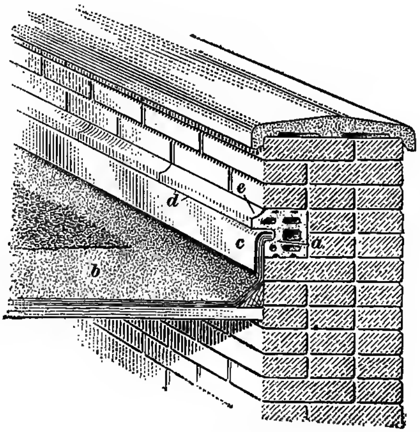


Fig. 11

When the walls are of concrete, a metal form having a slot or raggle of a shape similar to *e* in Fig. 12 is sometimes built into the concrete. Into this raggle, the flashing may be built in the same manner as just described.

27. The cap flashing and base flashing shown in Figs. 8 to 12 should be carried around both inside and outside corners, or angles, of walls, chimneys, or other breaks in the roof surface. At *f* in Fig. 9 is shown an outside angle, in which a strip of the flashing material *g*, 10 inches wide, is cut and folded to bend around the angle as shown. The flashing extends 4 inches out on the roof surface at *h*, is turned up 8 inches on the vertical surface, and is cemented and nailed to the roof surface at *i*. A strip of felt *c*, or one layer of the roofing felt, is cemented over the flashing in order to cover the nail heads. In the inside angle *j* a similar method is followed, the flashing being doubled on the roof at *k*. When all the flashing is in place, the slag or gravel top finish is applied to the roofing.

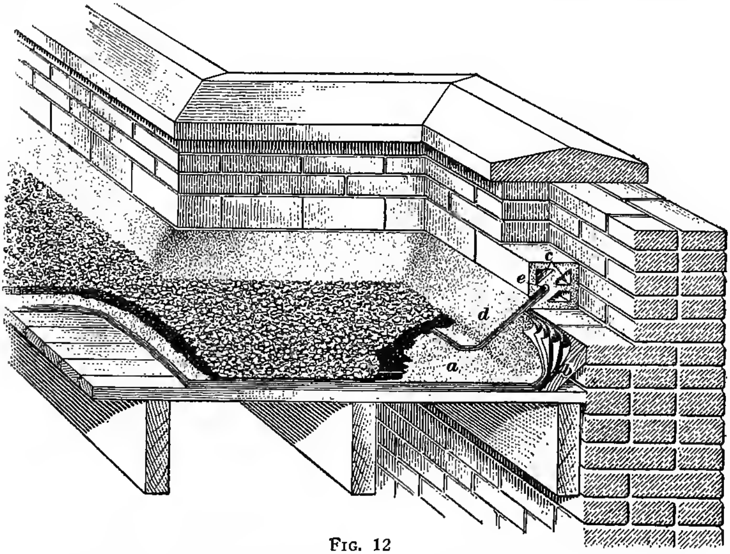


Fig. 12

28. **Eaves Stops.**—Where slag or gravel roofing is used, metal or wood *eaves stops* should be provided at the eaves and at gable ends or sides where the walls do not extend above the roof. The metal eaves stop *l*, Fig. 9, should extend not less than 4 inches on the roof, as at *m*, and sufficiently far down on the roof edge, as at *n*, to insure secure nailing. The lip *o* of the stop should be about ½ inch high, in order to stop any loose slag or gravel that might be carried down by a heavy rain. This eaves stop is often combined with the gutter or cornice, as shown at *j* in Fig. 1.

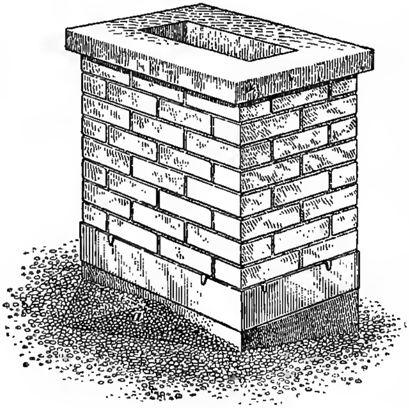


FIG. 13

29. Saddles. Where chimneys, scuttles, or bulkheads extend through the roof surface, *saddles*, *gussets*, or *crickets* are used, as at *a* in Fig. 13, to divert water around the object. The roofing is carried over these surfaces as over the other roof surfaces, and is flashed against the vertical surfaces as already described.

READY ROOFING

30. Ready, or **prepared, roofing** is made of two or more layers of saturated felt cemented together with asphalt. In some forms of ready roofing, a layer of burlap is cemented between the layers of felt, which gives the roofing additional tenacity.

The surface of ready roofing may be smooth or rough, or may have a layer of crushed slate or gravel cemented to and pressed into the surface so as to present a granular appearance. Red or green slate may be used, which gives the roofing a corresponding color.

31. Ready roofing is made in three weights, light, medium, and heavy, and is sold in rolls 32 and 36 inches in width. Each roll contains enough material to cover 1 square of roof, allowing for a 2-inch lap, and all the accessories needed for laying it, consisting of nails, caps, cleats, and cementing materials, are contained inside the roll as it is sold. One form of asbestos ready roofing is made in four plies of saturated asbestos felt and is sold in sheets. These sheets are 32 inches by 80 inches in size, six sheets being required for one square of roofing. The light-weight and medium-weight roofings are sometimes made in rolls containing material sufficient to cover 2 squares. Some forms of ready roofing are made to be laid with a lap of 3 to 6 inches, to provide a more water-tight joint, especially on roofs of low pitch. Where wide laps are provided, the gravel or slate surfacing is omitted at the top of the sheet where the lap occurs, especially when made of asbestos felt, or covered with crushed slate or gravel. This roofing is economical and easily applied. It is used generally on industrial buildings, sheds, and farm buildings, where appearance is not of great importance.

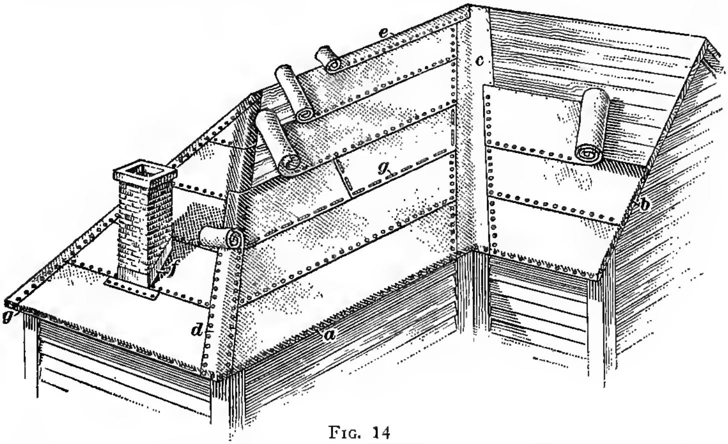


Fig. 14

32. Ready, or prepared, roofing can be successfully laid on roofs having a pitch of more than 3 inches to the foot, as illustrated in Fig. 14. For fastening the roofing to the boards, barbed nails *a*, Fig. 15, with large flat heads, are driven through tin disks, or caps *b*, which spread the grip of the nail and prevent its tearing through the felt. Cleats *c*, which require three or four nails, are also used. The application of these disks and cleats is illustrated in Fig. 14 at *a* and *g*, and in Fig. 16 at *c* and *d*.

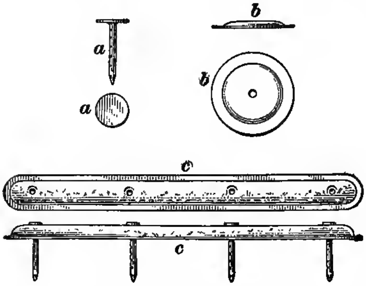


FIG. 15

33. Laying Ready Roofing.—Ready roofing is generally laid in strips parallel to the eaves, beginning at the eaves or lowest point of the roof *a*, in Fig. 14. The edges of the roofing are turned down over the eaves, and at the gable ends *b*, as shown at a larger scale at *a* and *b* in Fig. 16. The edges are held securely by nails driven through the caps *c*, or through cleats *d*. Both disks and cleats are not, however, used in the same roof. When it is necessary to join the ends of the roofing, a lap of 3 to 6 inches is made, as at *e*, Fig. 16, the laps

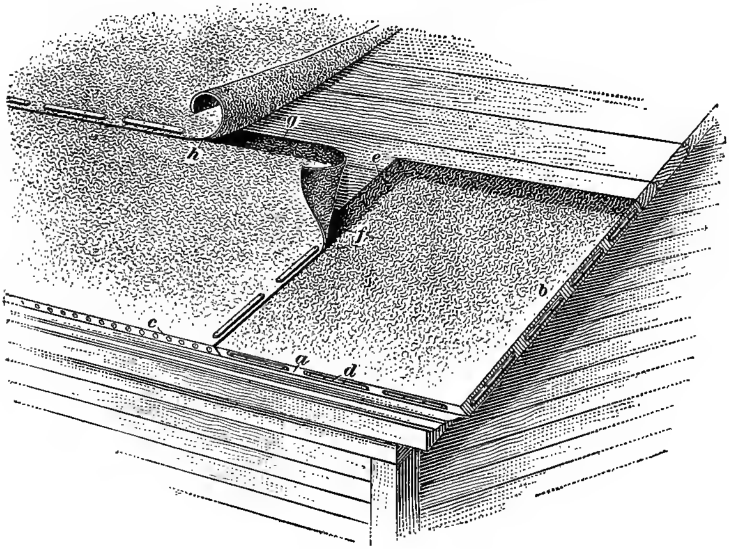


FIG. 16

being cemented together as at *f*, and the top sheet being held down by caps or cleats. The successive strips are lapped about 2 inches horizontally, or lengthwise of the sheets, as at *g*, and cemented together as at *h*. The strips are nailed through the bottom edge so as to catch the top of the sheet below, the nails being driven through caps or cleats.

Usually, on very steep roofs, it is best to lay the ready roofing in strips from the eaves to the ridge, as this aids in preventing buckling of the sheets. The overlapping edges and ends of the strips are cemented together and secured by caps and cleats.

34. Flashings for Ready Roofing.—Valleys are formed of strips of ready roofing to which the roofing strips are cemented, as at *c* in Fig. 14. The ends of the roofing strips are secured by nails and caps or cleats. At the hips the roofing strips are lapped over the hip about 2 or 3 inches, and a cap strip *d* 10 or 12 inches wide is bent over the hip, being firmly secured by cementing and by nails and caps or cleats. A similar method is used on the ridges, as at *e*. Sheet metal is applied sometimes in place of the ready roofing, for valleys, and for hip and ridge cap strips.

The intersections of ready roofing with other parts of the building, such as walls, chimneys, or bulkheads, as at *f* in Fig. 14, are flashed by turning up the roofing against the vertical surfaces for a distance of at least 6 inches, and applying a flashing of ready roofing securely cemented and nailed to the roof. This flashing is covered with a counterflashing, which may be of metal, such as tin, galvanized iron, copper, or of special flashing material as already described.

CANVAS ROOFING

35. Canvas roofing consists of a heavy, close-woven, cotton fabric, usually treated with substances that render it waterproof, tough and resistant to decay. The customary widths in which canvas roofing is made are 30 and 36 inches, although some manufacturers provide widths up to 72 inches.

Rolls of practically any length may be obtained, so that pieces may be cut for the entire length of ordinary roofs. The weight of canvas is designated by the number of ounces to the square yard, the canvas used for roofing varying from 14 to 24 ounces, depending on the wear to which the roofing will be subjected.

36. Where Canvas Roofing Is Used.—Canvas roofing is used for roof surfaces of very slight pitch which are subject to severe wear, such as the roofs of balconies, and for decks of boats. It is also used for such places as floors of kitchens, laundries, and porches. Canvas may also be used for lining valleys and gutters, and for flashing. It may be laid with as little pitch as ¼ inch to the foot.

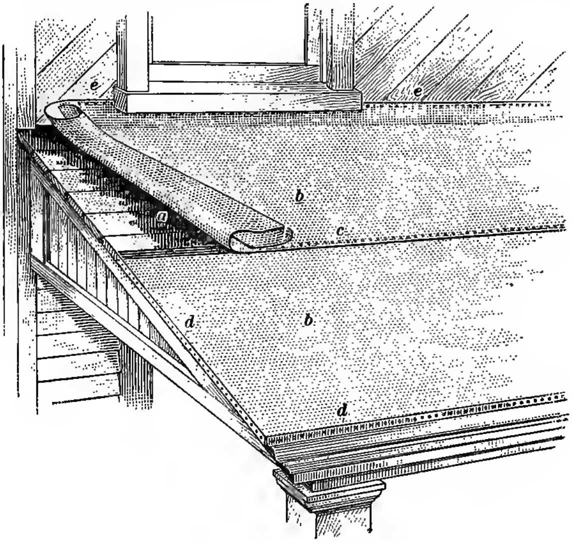


Fig. 17

37. Advantages of Canvas Roofing.—Canvas roofing is light in weight, easy to lay, durable, and clean. It will not crack like sheet metal nor tear like felt, if walked upon. It can easily be renovated by a coat of oil paint. The flexibility of canvas makes it suitable for roofing railway cars, which are subject to vibration.

38. Laying Canvas Roofing.—The roof is prepared for covering with canvas by painting the roof boards with a coat of paint, as at *a* in Fig. 17, either of white lead and oil, or of a bedding paint prepared for the purpose. In this paint while wet, the canvas *b* is laid. With some grades of canvas no paint is required before laying, the canvas being laid directly on the roof boarding. The canvas is drawn and stretched tightly, so as to overcome any tendency to buckling, and is secured to the boarding by means of flat-headed copper or galvanized nails placed not more than ¾ inch apart, as at *c*. The strip at the lower edge of the roof is laid first, the succeeding strips lapping 1½ to 2 inches. At the eaves and edges of the roof, the canvas is nailed at ¾-inch intervals, as at *d*. After laying, the roofing is given one coat of paint, although two coats will be better if the wear is to be severe.

39. Flashings for Canvas Roofing.—Separate flashings are not used generally with canvas roofing. The edges of the canvas are turned up against the walls, and when used with frame buildings, the canvas may extend up on the sheathing as at *e*, and be covered by the siding. When used against masonry walls, the canvas is turned up against the wall, and covered with counterflashing, as already described.

IRON AND STEEL ROOFING

40. Materials.—Iron and steel, in the form of sheets or plates, are used for roofing. In making these sheets, great care is used to obtain a product that will resist the tendency to rust, and that will have the necessary toughness and ductility to permit its being worked into the shapes required in roofing. Some manufacturers claim to get the best results by making a very pure iron, while others believe that better qualities are obtained by mixing in small quantities of certain other metals, such as copper and manganese. Whatever the materials, the mixture must be uniform in composition, compact in texture, and free from isolated particles of foreign material that may prove to be points of weakness, or starting points for rust or corrosion.

41. Black, or plain, sheets are sometimes used, although more commonly the sheets are galvanized. *Galvanizing* is a process of covering iron or steel plates with zinc, for the purpose of preventing the rapid oxidation that takes place when iron or steel is exposed to atmospheric influences.

TABLE II

UNITED STATES STANDARD GAUGE FOR THICKNESS AND WEIGHT OF SHEET AND PLATE IRON AND STEEL

Number of Gauge	Approximate Thickness in Fractions of an Inch	Approximate Thickness in Decimal Parts of an Inch	Weight per Square Foot in Ounces Avoirdupois	Weight per Square Foot in Pounds Avoirdupois
16	$\frac{1}{16}$	.0625	40	2.5
17	$\frac{9}{160}$	.05625	36	2.25
18	$\frac{1}{20}$	.05	32	2.
19	$\frac{7}{160}$	.04375	28	1.75
20	$\frac{3}{80}$	.0375	24	1.50
21	$\frac{11}{320}$	.034375	22	1.375
22	$\frac{1}{32}$	.03125	20	1.25
23	$\frac{9}{320}$	.028125	18	1.125
24	$\frac{1}{40}$	.025	16	1.
25	$\frac{7}{320}$	.021875	14	.875
26	$\frac{3}{160}$	.01875	12	.75
27	$\frac{11}{640}$	.0171875	11	.6875
28	$\frac{1}{64}$	.015625	10	.625
29	$\frac{9}{640}$	.0140625	9	.5625
30	$\frac{1}{80}$	.0125	8	.5
31	$\frac{7}{640}$	.0109375	7	.4375
32	$\frac{13}{1280}$	.01015625	6½	.40625

42. Gauge.—The thickness and weight of sheets or plates of iron and steel are designated by the gauge number, which represents definite weights in pounds avoirdupois to the square foot. Table II gives some of the thicknesses and weights according to the United States Standard Gauge, which is established by the United States Government. This table shows the weights of iron and steel commonly used for roofing purposes. The complete table of the United States Standard Gauge shows thickness, and weights of metal weighing from 20 pounds to the square foot, known as No. 0000000 gauge, to $\frac{1}{4}$ pound to the square foot, known as No. 38 gauge. This gauge refers to iron and steel sheets only, and is not used for other metals.

43. Forms of Roofing.—The principal forms in which iron and steel sheets are used for roofing are known as *roll roofing, pressed standing-seam roofing,* and *corrugated roofing.*

ROLL ROOFING

44. Roll roofing is made of iron or steel plates or sheets, 26 to 28 inches wide, and about 5 feet in length. The thickness or gauge of the sheets is usually from No. 26 to No. 30. The iron is either black or galvanized, the latter being preferable. These sheets are joined together at the ends to make strips about 50 feet long. One such strip is sufficient to cover 1 square of roof surface. These strips are rolled up as shown in Fig. 18. From this fact this form of roofing is known as *roll roofing.*

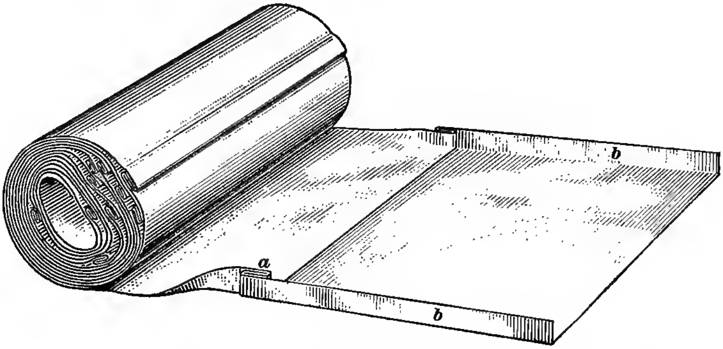


Fig. 18

In joining the sheets to form the strips, cross-seams, shown at *a,* in Fig. 18, are used. These seams are made with a *single* *lock*, as shown at *a* in Fig. 19, or with a *double lock* as at *a* in Fig. 20. The double-lock seam offers more resistance to the passage of water through the joints than the single seam. Moreover, as these seams are not soldered, the double-lock seam is less likely to come apart than the single-lock seam. The single-lock and the double-lock seams are also used for other forms of roofing, and are sometimes referred to as *flat-lock seams*.

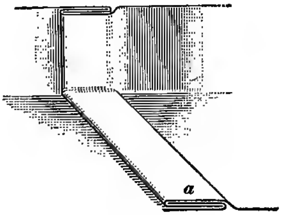


FIG. 19

45. This form of roofing is used for roofs of industrial buildings, farm buildings, and for buildings where the appearance of the roof is of less importance than the protection that the roof affords. This form of roofing is adapted to roofs having a pitch of 2 inches or more to the foot. As considerable of the work of preparing the roofing is done on the roof, the work becomes more difficult as the pitch of the roof increases beyond the angle at which a workman can stand.

An example of a roof covered with roll roofing is shown in Fig. 21. At *a* is the finished roof, at *b* a strip of roofing with the edges bent, and ready to be placed against the sheet *c*. At *d* are the eaves; at *e* is the gable end; at *f* is the ridge; at *g* are the hips; and at *h* is a valley. There are differences in the methods used in joining the sheets, but the general effect of the roof is such as is illustrated in the figure.

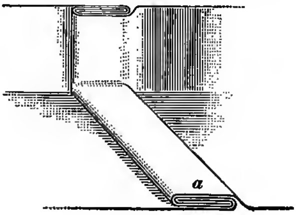


FIG. 20

46. Preparation.—The roofing, shown in Fig. 18, is unrolled and the edges bent up as shown at *b*, the bent-up portions being from 1 to 1¾ inches in height. The roof is covered with roofing boards laid tightly together. Felt or sheathing paper is not used, as a rule, under this form of roofing, although the use of these materials tends to preserve the roofing from the injurious effects of gases and moisture in the

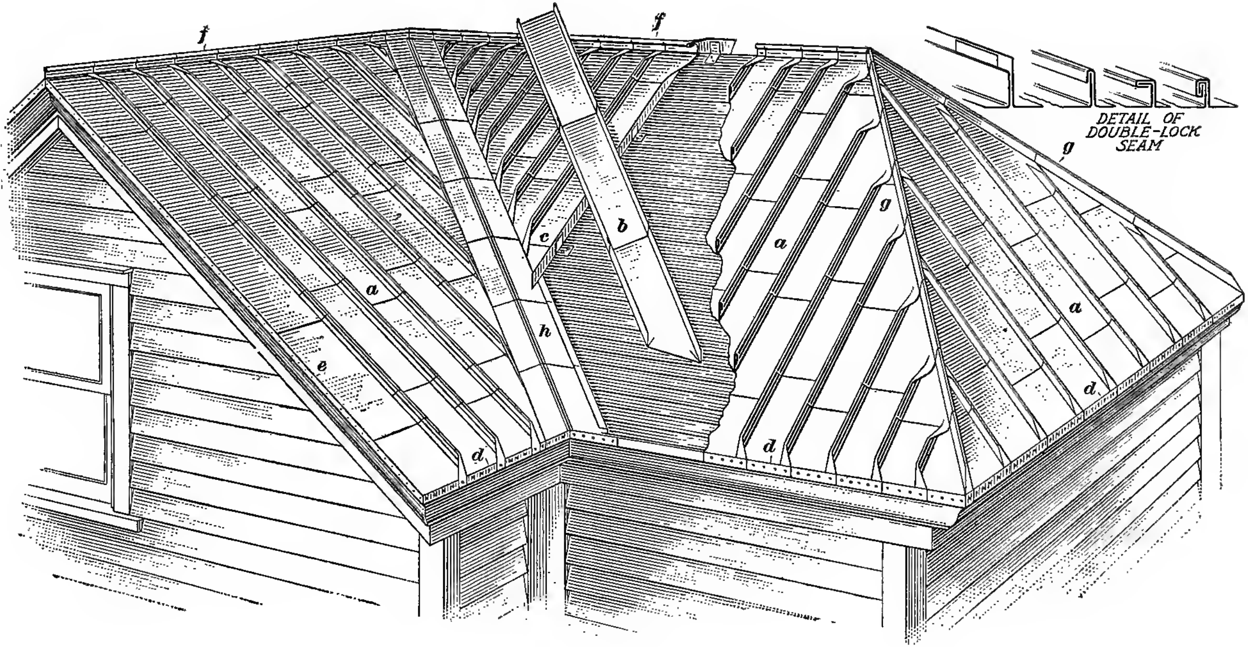


FIG. 21

building. The strips or rolls are cut into proper lengths, as shown at *b* in Fig. 21, and are joined together with one of the following forms of joints.

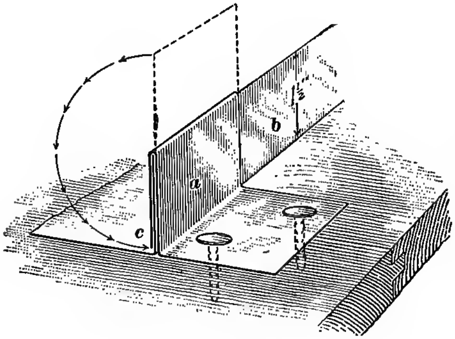


FIG. 22

47. Joints. There are two types of joints used in connecting two strips of roofing such as *b* and *c* in Fig. 21. One is the *self-capping standing-seam joint*, and the other is the *roll-and-cap joint.*

48. Standing-Seam Joints.—Standing-seam joints may be single-lock or double-lock seams.

A single-lock standing-seam joint is illustrated in Figs. 22, 23, and 24, in which the successive processes in making this joint are shown. Cleats *a*, Fig. 22, are nailed to the sheathing, at 12-inch intervals, against the upturned flange *b* of a strip of roofing previously laid. The cleats hold the roofing firmly in place, the ends of the cleats being bent down over the upturned edge of the sheet. The cleat should be long enough to reach nearly or quite down to the roof, as at *c*. The next strip of roofing is placed over the cleat and against the first strip as shown in Fig. 23. The edge is bent up 1 inch, while the edge of the first strip is bent up 1½ inches. The top of the cleat *a* and the top of the flange *b* are then bent down over the flange *d* as shown in Fig. 24. The top of this seam is about 1 inch above the roof surface. The seam is then pressed together tightly.

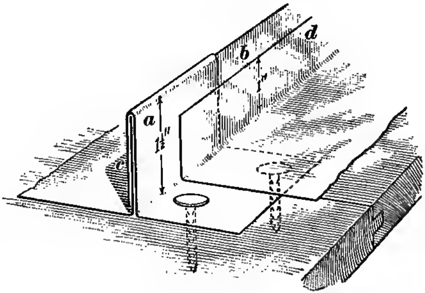


FIG. 23

49. A double-lock standing-seam roof is begun by bending up the edges of a strip of roofing 1½ and 1¾ inches, as shown at *a* and *b* in Fig. 25. Cleats *a*, Fig. 26, are nailed to the roof boards to hold the roofing firmly in place. The top of the cleat reaches only to the top of the upturned edge of the flange *b*, or 1¾ inches. The next sheet of roofing *c*, Fig. 27, is placed over and against the cleat *a*. The flange is only 1½ inches in height. The ¼-inch projection of the flange *b* above the flange *d*, together with the ends of the cleats *a*, are folded over the top of the flange *d*, as shown in Fig. 28 (*a*). A section of the seam is shown in (*b*). The seam is immediately folded again, and tightly pressed together, as shown in Fig. 29 (*a*). This completes the seam, which stands about 1¼ inches above the roof. In this double-lock seam, the cleat is folded securely into the seam, as shown

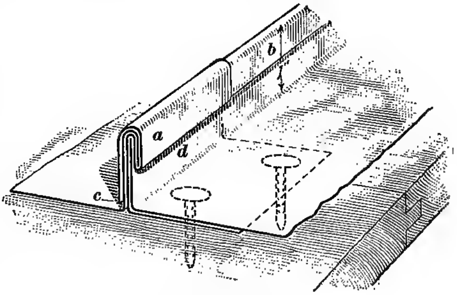


Fig. 24

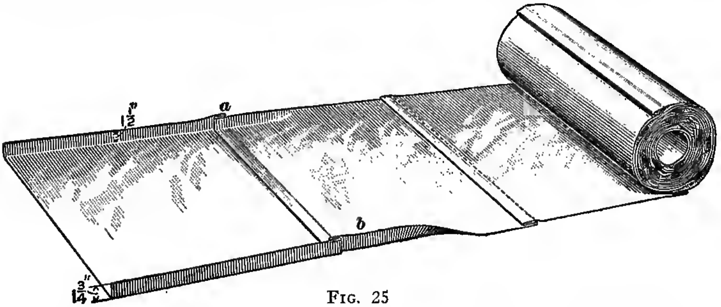


Fig. 25

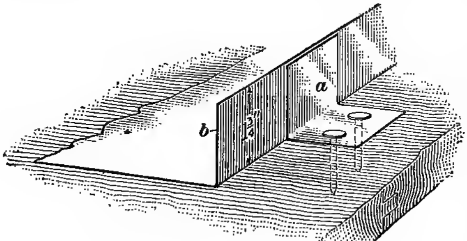


Fig. 26

in (*b*), and holds the roofing to the boarding. This joint is more water-tight than the single-lock standing-seam joint.

These joints can be formed as shown, or the reverse. The fold in the latter case will be to the left. A detail of a double-lock seam, showing the progressive steps in forming it, is given in the upper right-hand corner in Fig. 21.

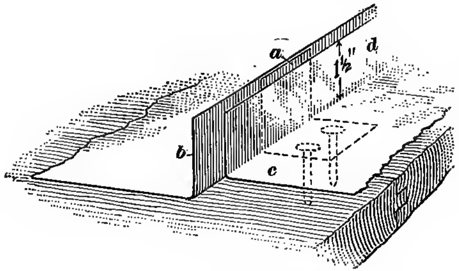


FIG. 27

50. Roll-and-Cap Roofing. Roll-and-cap roofing, or standing-seam roofing with cap, is shown in Figs. 30 and 31. In these figures the same reference letters are used for the corresponding parts. This roofing differs from the standing-seam roofings already described in that the turned-up edges *a* of the sheets *b, c,* and *d* are not locked together, and are of the same height. The sheets of roofing are held down by cleats *e,* and the flanges are covered with a special cap *f* which covers the openings between the flanges, and forms a satisfactory seam. In starting the roof at the eaves and gables the edges of the roofing are bent down and nailed, as at *g,* Fig. 30.

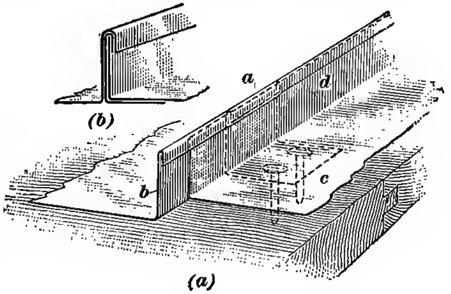


FIG. 28

The joint, or seam, is formed by placing one strip of roofing *b,* Fig. 31 (*a*) and (*b*), on the roof, and placing cleats *e* against the flange. These cleats are about 2 inches wide, are spaced about 12 inches apart and securely nailed. A second strip of roofing *c* is placed against these cleats, and the cleats, which are split at the top, as at *h,* are bent down over both flanges as at *i* and *j.* Over the tops of the cleats and

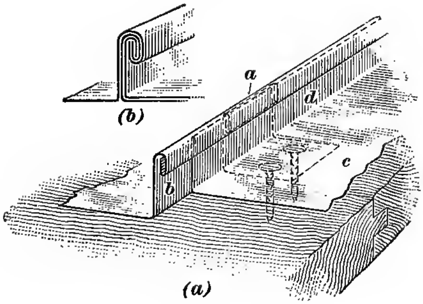


FIG. 29

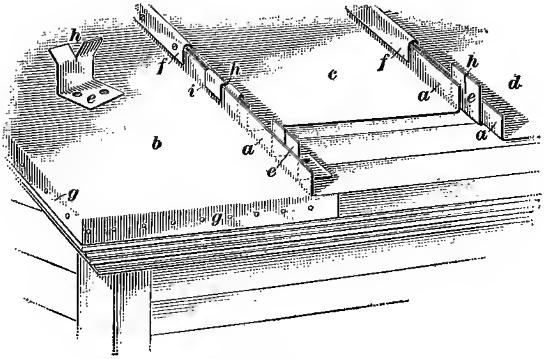


FIG. 30

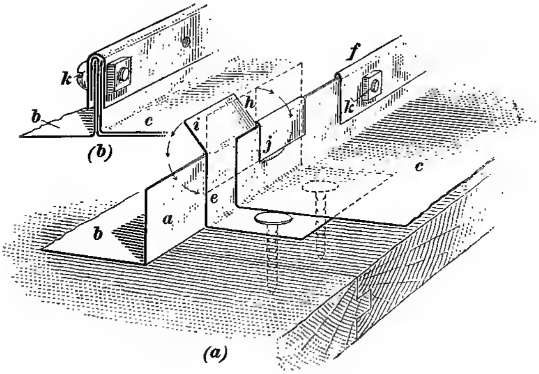


FIG. 31

flanges a cap *f* is placed, and is fastened by bolts *k*, in (*a*) and (*b*), that go through the cap and the flanges. Sometimes the cap is merely pressed by tongs which indent the cap but do not perforate it, so as to hold it firmly to the flanges and cleats without being bolted.

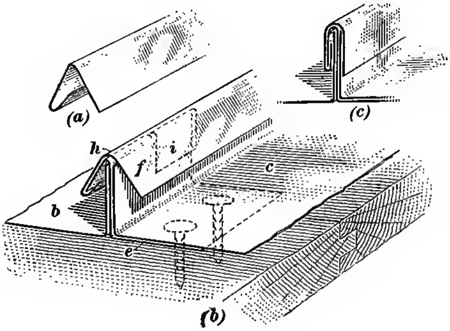


Fig. 32

51. The cap is also sometimes made with a turned edge as in Fig. 32 (*a*). This edge is caught under the ends of the cleats as in (*b*) and the cap pressed tightly against the flanges as in (*c*). This treatment secures the cap firmly in place.

Still another method that is used for securing the cap over the flanges is shown in Fig. 33. In this method, a slit *g* is made in the cap *f*. The flanges of the cleats project through this slit and are bent over as shown at *h* and *i*, thus holding the cap firmly in place.

52. Finish at Eaves.—In Fig. 34 is shown a method of finishing the roof at the eaves, when a gutter is used. The roof has standing seams as shown at *a*. The gutter extends up on the roof surface as shown at *b*, and the roofing is locked into the flange *c* of the gutter. The outside edge of the end sheet on the roof is bent down over the gable end about 1 inch, and nailed at intervals of about 2 inches, as at *d*.

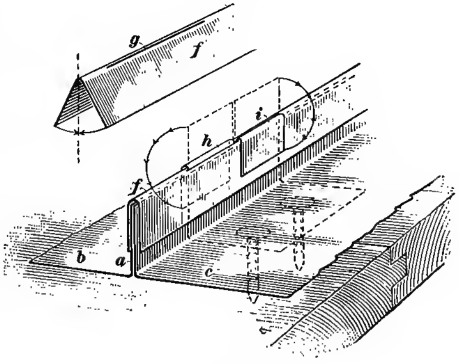


Fig. 33

When no gutter is used, the roofing is turned down over the edge of the eaves, and securely nailed, as at *a* in Fig. 35.

53. Finish at Ridges.—Ridges may be finished as shown in Fig. 36. The roof strips are cut to extend about 2 inches above the ridge on one side, and ¼ or ½ inch longer on the other side. The standing seams of the roofing are flattened, as at *a*, so that they may be folded into the lock seam of the ridge.

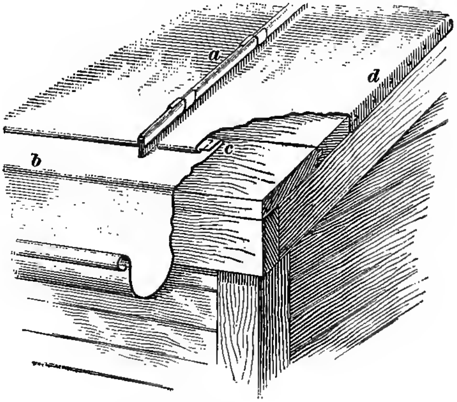


FIG. 34

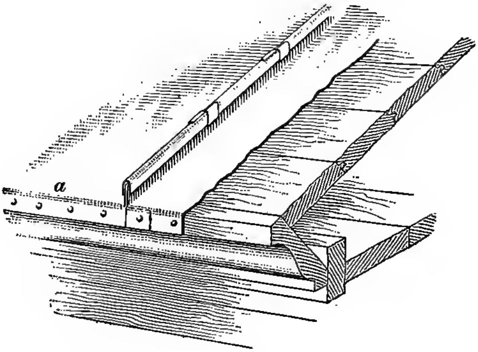


FIG. 35

Cleats are nailed to the roof boarding at 12-inch intervals, and a single-lock seam is formed, as at *b*.

Another method of finishing a ridge is shown at *a* in Fig. 37. No cleats are used in this method. The roofing strips are lapped over each other at the ridge, as shown, and nailed. The seams of the roofing are flattened in this method, as shown.

54. Finish at Hips.—Hips are made, in this type of roofing, by cutting the strips to the proper angle, and allowing 2 inches in the length. A single-lock joint is then formed as for a ridge. The seams in the roofing are also neatly flattened as shown in Fig. 21.

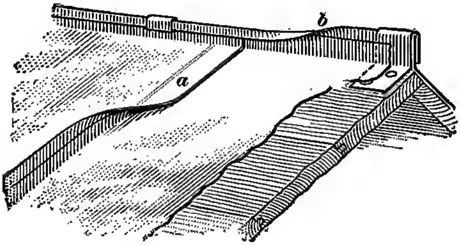


FIG. 36

55. Finish at Valleys. — Valleys are usually formed of full-width strips of the roofing, laid from bottom to top of the valley, care being observed to have the cross-seams *a*, Fig. 38, so laid that the water will run over the seam instead of against it. The edges *b* of the valley strip are turned over $\frac{1}{2}$ inch to form a single-lock seam, and are fastened with cleats *c* at 12- or 14-inch intervals. A corresponding lock *d* is formed on the lower edge of the roofing strip *e*. This strip is fitted against the strip *f*, already in place, and locked into the valley strip. The seam at *b* is flattened down, making a tight joint.

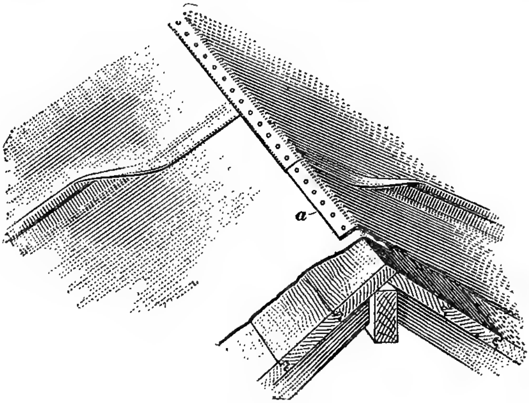


FIG. 37

56. Flashings for Roll Roofing.—Flashings against vertical surfaces, such as walls, are formed by turning up the roofing metal about 6 inches. When used on frame buildings, this flashing usually will be covered by the siding of the vertical wall. In brick or masonry buildings, the flashings will be covered by a counterflashing of the same metal as the roofing, in the same manner as already described.

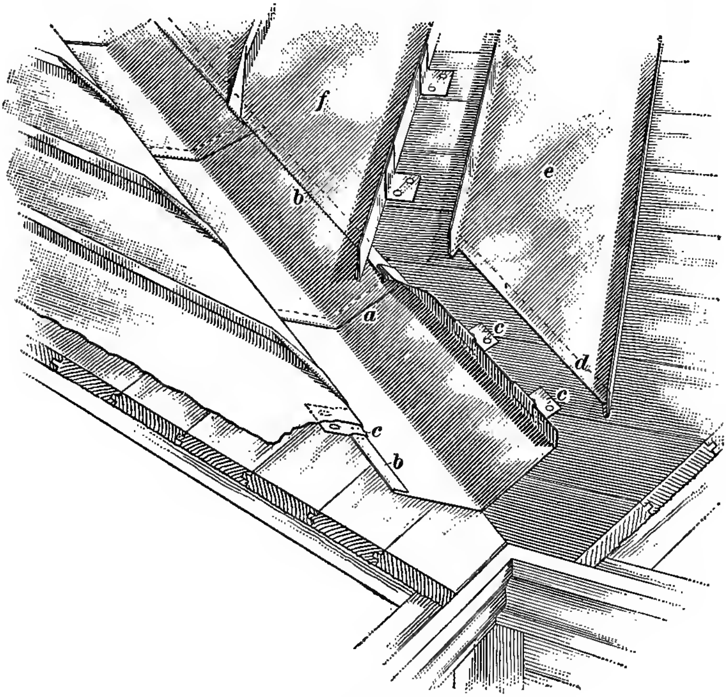


FIG. 38

PRESSED STANDING-SEAM ROOFING

57. Sheet-metal plates of various sizes are made or pressed into shapes in which the side seams are included, so that they are ready to lay on the roof without the necessity for forming the side seams. The principal types of this roofing are known as *pressed standing-seam roofing* and **V**-*crimp roofing*. The sheets may be used for either roofing or siding. This roofing may be laid on a roof having a pitch of 3 inches or more to the foot. Galvanized sheets are preferable, although black sheets are largely used.

58. Pressed Standing-Seam Roofing.—The sheets commonly used for pressed standing-seam roofing are of metal about 28 inches wide and from 5 to 12 feet long. As about 4 inches is taken up in forming the side seams, the finished width of the sheet is about 24 inches. The sides of the sheet are pressed into a **U** shape about 2 inches high, as shown in the sheet *j*, Fig. 39. The ends of the sheet are slit 2 inches, for turning a lock on the ends, as shown at *k*.

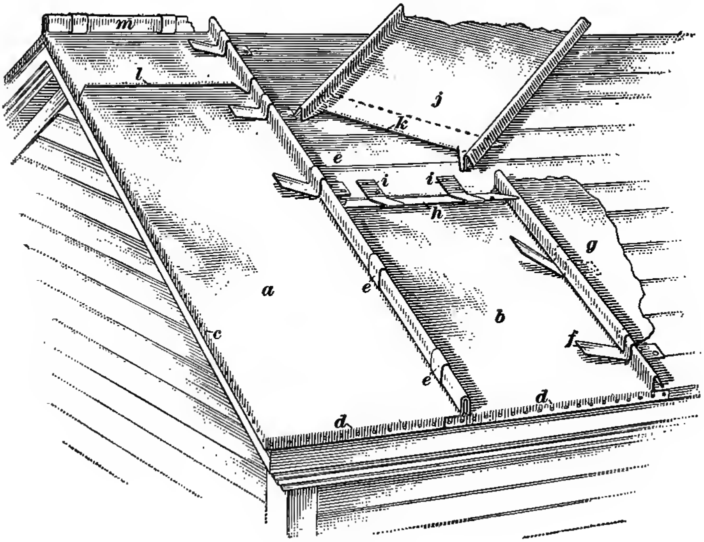
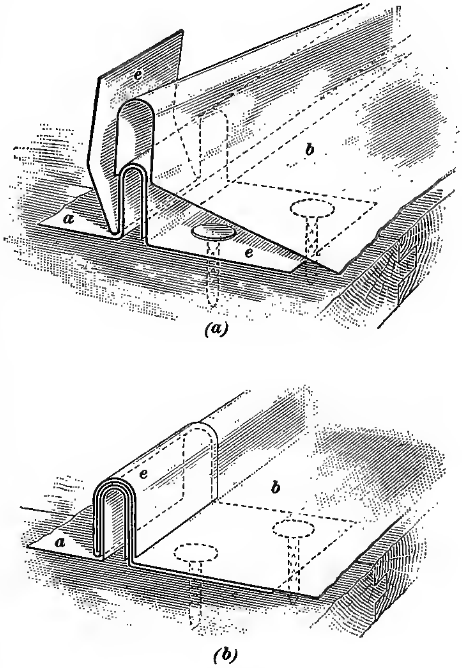


Fig. 39

59. Laying Pressed Standing-Seam Roofing.—The method followed in laying standing-seam roofing is illustrated in Fig. 39. Sheets *a* and *b* are shown in place. The left-hand edge *c* of the first sheet laid is turned down and nailed to the gable end, and the lower edge *d* of the sheet is turned down and nailed at the eaves. Cleats *e* are used to hold the sheets in place. The cleats are laid over the edge of the sheet and bent over the up-standing edge, and down to the roof surface, leaving the end extending out as shown at *f*. The overlapping sheet is laid over the cleat as at *g*, after which the end of the cleat is bent over the overlapping sheet as at *e*. The cleat and the standing seams are then pinched together tightly by means of tongs.



(*a*)

(*b*)

Fig. 40

60. Half sheets, as at *b*, Fig, 39, are used to break the horizontal joints across the roof. The cross-seams at the upper end of the sheet *b* are made by turning over the upper edge *h* of the sheet. Cleats *i* are turned down and under the edge *h*. The lower edge of the next sheet *j* has its lower edge *k* turned under, as shown by the dotted lines, so as to form a single lock with the edge *h*. The joint is then hammered flat, as at *l*. The ridge *m* may be finished in the same manner as in standing-seam roofing. Hips and valleys may be finished by any of the methods described for standing-seam roofing.

61. In Fig. 40 (*a*) is shown a diagram of a side seam. The first sheet *a* is in place, and the cleat *e* has been nailed to the roof, holding down the sheet *a*. The second sheet *b* is shown as it is being lowered to its final position. In (*b*) is a diagram of the completed joint, the sheet *b* having been pressed down to its final position, and the cleat *e* folded over to hold down the sheet *b*.

62. V-Crimp Roofing.—The sheets used for **V**-crimp roofing, shown at *a* in Fig. 41, are formed in a manner similar to pressed standing-seam roofing, but the edges or crimps *b* are in the form of inverted **V**'s. The ends of the sheets are slit, as at *c*, to permit turning a lock, the same as described for pressed standing-seam roofing.

63. Laying V-Crimp Roofing.—In laying **V**-crimp roofing, triangular wood strips *d*, Fig. 41, are nailed to the roof boarding, to serve as nailing strips for the sheets. These strips are placed, usually as the laying progresses, under the outside edge of the sheet last laid, as at *e*, although they may be laid over all the roof at one time by observing carefully the spacing of the crimps at the edges of the sheets. When starting at a gable end, the **V** is flattened down so as to extend over the edge of the roof surface, as at *f*, and is securely nailed. The sheets are then laid in continuous rows from eaves to ridge.

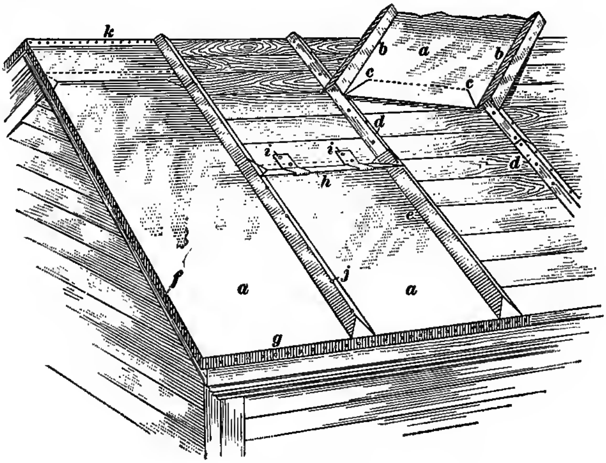


Fig. 41

The lower edge of the first sheet is turned down a sufficient distance to cover the edge of the eaves, as at *g*, Fig. 41, or to lock into the gutter in the same manner as described for roll roofing. The upper edge, as at *h*, is formed to make a 2-inch single-lock seam. Cleats *i* are used to secure the sheet at the top. The crimp of each sheet is laid lapped over the crimp of the sheet just laid, as shown, and is nailed through the top of the crimps at 8- or 10-inch intervals with 1¾-inch barbed nails *j*. The ridge is formed by lapping the sheets over each other as at *k*. The hips and valleys are formed in a manner similar to that described for pressed standing-seam roofing.

This form of roofing is also made with a double crimp at each edge, with a center crimp, or with the portion between the crimps corrugated or stamped to represent shingles or other patterns.

64. Flashings.—Roofs on which pressed standing-seam roofing plates are used are flashed and finished in the same manner as described for roll roofing.

CORRUGATED ROOFING

65. Corrugated roofing is made usually from steel or iron plates or sheets. Copper is used sometimes for this purpose, as are also steel plates covered with an asphalt preparation to resist the action of gases, and with asbestos to aid in making the material fire resisting. A typical corrugated metal sheet is shown in Fig. 42.

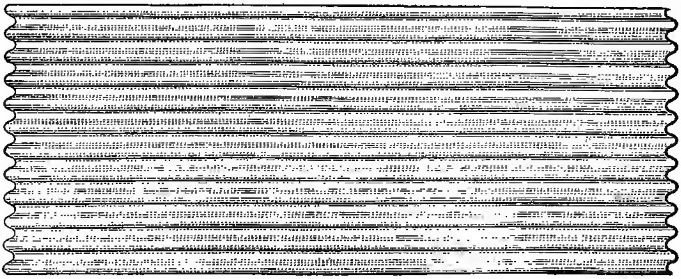


FIG. 42

The metal sheets ordinarily used for roofing are from No. 16 to No. 28 gauge, and vary in weight from No. 16 at 40 ounces to No. 28 at 10 ounces to the square foot. The standard width of sheets is 26 inches, which, with 2-inch side lap, will cover 24 inches. The sheets may be obtained in 6-, 7-, 8-, 9-, 10-, and 12-foot lengths. The corrugations vary from $\frac{5}{8}$ inch to $2\frac{1}{2}$ inches in width. This form of roofing is used in mills and factories where utility and economy are prime considerations.

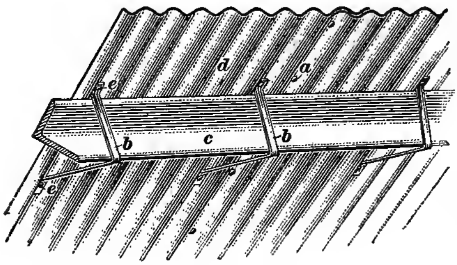


Fig. 43

66. Preparation of Surface.—The surface to be covered with corrugated roofing may be sheathed with tight boarding, or it may have horizontal wood purlins, or metal purlins as shown in Figs. 43, 44, 45, and 46. The thickness of the metal roofing used will determine the distance between the supports on which the sheets are laid. The lighter gauges are laid on close sheathing, while the heavier gauges can be laid on purlins spaced from 2 feet to 5 feet apart. Corrugated metal, having little strength in a direction perpendicular to the corrugations, must have continuous supports in that direction. The pitch of the roof on which the corrugated sheets are laid should be not less than 3 inches to the foot.

67. Laying Corrugated Roofing. The direction from which the heaviest winds and rain come determines the end from which the laying of the roof is started. If from the right, the roofing should start from the left, so that rain will not be driven into the joints of the overlapping sheets. When the roof is supported on wood boarding, the nails should

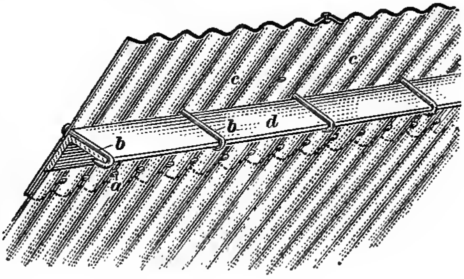


Fig. 44

be driven through the sides and ends of the sheets only, and vertically through the metal. The roofing is laid usually in courses across the roof, with joints lapped but not broken. As it is easy to get out of line, the roofing should be laid to chalk-lines or other guides, both vertically and horizontally. The laps may be laid in thick paint or elastic cement to aid in securing a water-tight joint, and lead washers may be used on the nails for the same purpose. For steep roofs, a 3-inch end lap is enough, while side laps should be not less than $1\frac{1}{2}$ corrugations. Felt lining should be used under the sheet metal laid on wooden boarding when hot air, steam, fumes, or gases are formed in the building.

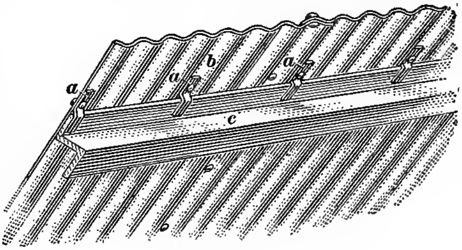


Fig. 45

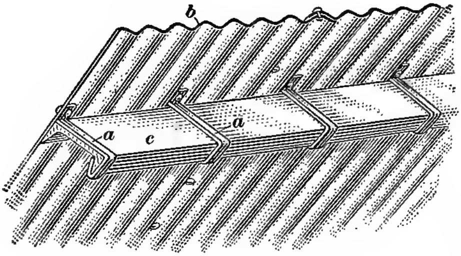


Fig. 46

68. For roofing on steel framing, side laps should be riveted every 12 or 18 inches, as shown at *a*, Fig. 43, and the end laps in every corrugation, as shown at *a* in Fig. 44. The sheets are laid so that cross-seams occur only at the supports, as shown.

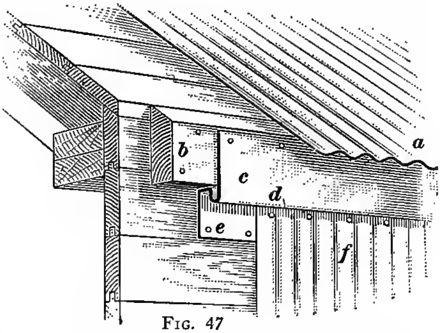


Fig. 47

For fastening the sheets to iron beams and purlins, one of the best methods is shown in Fig. 43. A cleat of band iron *b*

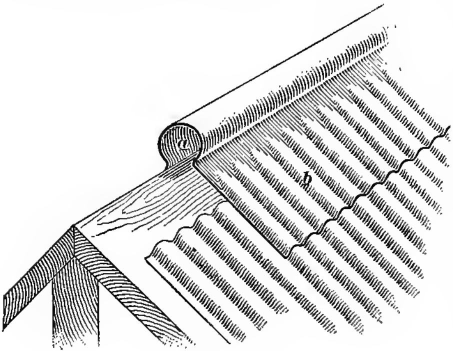


FIG. 48

¾ or ⅞ inch wide is passed around the angle *c*, and riveted at both ends to the sheet *d*, as at *e*. This view, together with those shown in Figs. 44, 45, and 46, shows the under side of the roofing. In the method shown in Fig. 44, a long wire or clinch nail *b* is driven through the corrugated sheet *c* and is bent around the angle *d*. In Fig. 45 is shown a cleat *a* made of bar iron, riveted firmly to the corrugated sheet *b*, and binding against the flange of a **Z** bar *c*. In Fig. 46 one end of a strap

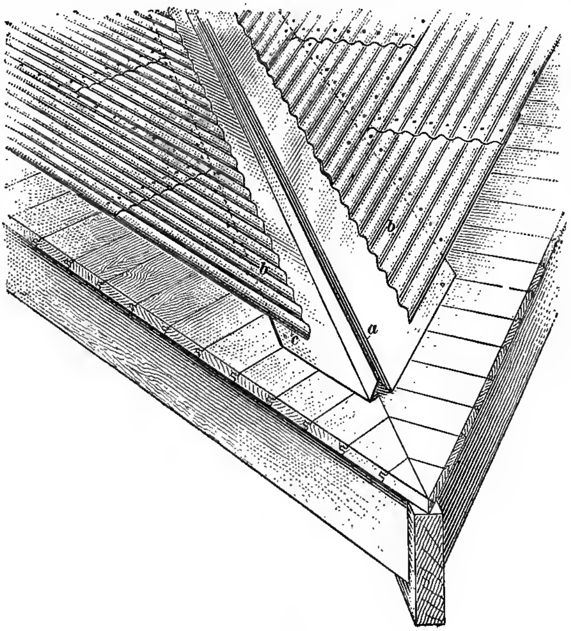


FIG. 49

iron cleat *a* is riveted to the sheet *b*, and the other end is bent around the flange of a channel purlin *c*.

69. Finish at Eaves.—A satisfactory finish may be made at the eaves of a building by extending the sheets several inches over the eaves as shown at *a* in Fig. 47. A wooden strip *b*, with the top beveled to fit the pitch of the roof, is nailed to the sheathing. A metal fascia *c* having a drip *d* is then nailed to the wooden strip and to the sheathing as at *e*. Corrugated sheet metal used as siding is shown at *f*, and is cut so as to fit up against the under side of the strip *b*. The drip *d* prevents water from entering at the top of the siding.

70. Finish at Gable Ends.—Gable ends are finished by bending down the edge of the sheet and nailing to the edge molding, or other support. The sheet should not extend out over the gable ends, as there is not sufficient strength in the metal in this direction to support it.

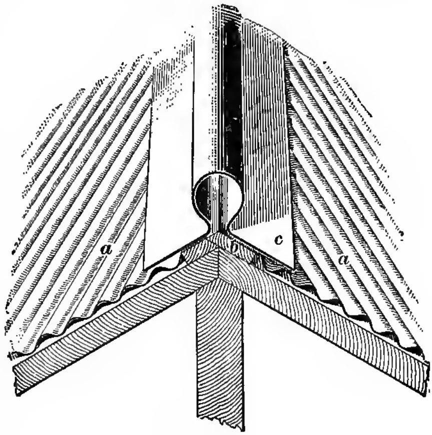


Fig. 50

71. Finish at Ridges.—Ridges should be finished with a ridge roll, or cap, *a*, as shown in Fig. 48, having an apron, or wing, *b* corrugated to match the sheets.

72. Finish at Valleys.—Valleys should be formed of plain galvanized sheets, preferably with a **V** center, as shown at *a* in Fig. 49. These sheets should be from 18 to 24 inches wide with the ends lapped at least 6 inches. The corrugated sheets *b* are cut to the proper angle, and fitted over the valley, the sheets lapping for a distance of 6 inches over the edges, as at *c*.

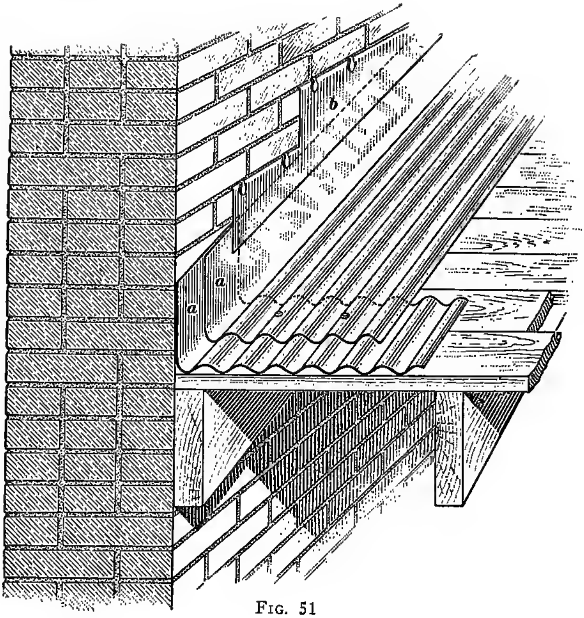


FIG. 51

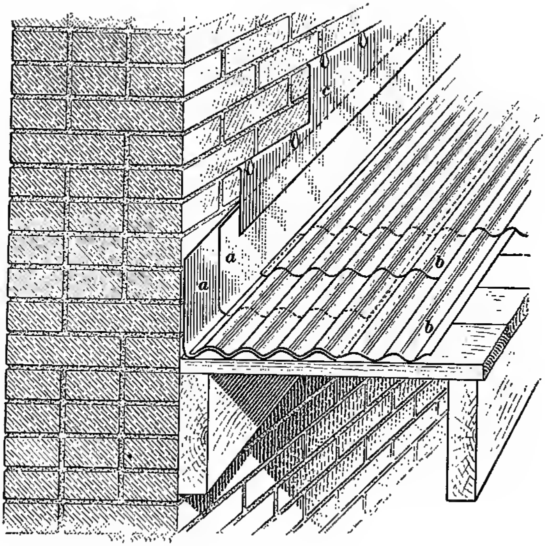


FIG. 52

73. Finish at Hips.—Hips should be finished as shown in Fig. 50, by cutting the sheets *a* to fit against the hip strips *b*, and then covering the joint with a hip cap, or roll, *c*.

74. Flashings for Corrugated Roofing.—Where the corrugated sheets abut against a fire-wall, a flashing may be made by flattening out an edge *a*, Fig. 51, and turning it up on the wall about 6 inches, and covering with a counterflashing *b*. Another method, shown in Fig. 52, is first to lay a flashing *a*, carry the roofing *b* over it, and afterwards to apply the counterflashing *c*. The flashing *a* has the roof portion corrugated to match the roofing.

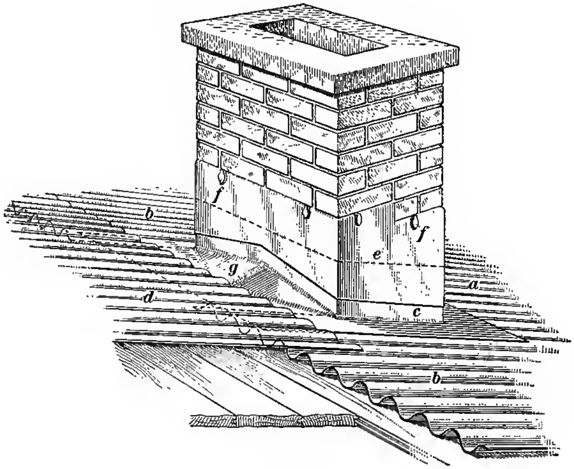


Fig. 53

75. In fitting around chimneys and bulkheads, the sheets on the lower side *a*, Fig. 53, and on the flanks *b*, abut against the masonry. A flashing *c* laps the surfaces *a* and *b* at least 6 inches, extends up on the roof sheathing, and is covered at least 6 inches by the sheets *d*. This flashing should be counterflashed, as at *e*, the counterflashing being secured by wall hooks *f*. Where the chimney is very wide, a saddle *g* is necessary to carry off the water properly.

TIN ROOFING

TIN AND TERNE PLATE

76. **Tin and terne plates** are made of soft steel or iron sheets coated on both sides with tin or a mixture of tin and lead. When pure tin is used for coating, the plates are known as *bright tin plates*. For roofing purposes, the plates are coated usually with a mixture of tin and lead. Such plates are known to the trade as *terne plates,* but are commonly called *tin,* or *tin plate*.

Terne plates are coated with mixtures varying from 2 parts tin and 3 parts lead to 1 part tin and 4 parts lead. The weight of the coating varies from 8 to 60 pounds to the standard box, which consists of 112 plates 20 inches by 28 inches in size. The weight of the coating is independent of the proportions of tin and lead in the coating.

77. **Gauge** denotes the weight and approximate thickness of the sheets to which the coating is applied. The gauges commonly used for roofing are No. 30 U. S. Standard Gauge (see Table II) having a weight of 8 ounces to the square foot, and No. 28 gauge, weighing 10 ounces to the square foot. These weights of sheets are known by the letters IC for the No. 30 gauge, and IX for the No. 28 gauge. The gauge of the sheet has no relation to the weight of the coating which is applied to it. IC plates are used for the main part of the roof. The IX plates are used for gutters, valleys, conductors, flashings, and similar work, and should be heavily coated.

78. The size of the plates is marked on the boxes in which they are shipped. The common sizes for roofing are 14 inches by 20 inches, and 20 inches by 28 inches. The box is also marked with the weight of the coating. Thus, a typical marking is "CHARCOAL IC 20×28—40," the word charcoal referring to the brand or grade, the IC to the weight of the steel or iron sheet, and the 40 meaning that 40 pounds of the mixture of tin and lead was applied to the box of 112 plates 20 by

28 inches in size. Perfect plates are stamped usually with the brand, gauge, and weight of the coating, and are called *primes.* Imperfect plates are called *wasters,* and are not stamped.

Brands are the different marks or devices used by tin-plate makers to identify their products. Reliable manufacturers always endeavor to maintain a uniform merit in the different brands which they turn out. The best grades of roofing plates always have the brand stamped on the plate, as well as the weight of the sheet and the weight of the coating. For roofing purposes, it is well for the architect to specify a brand of tin that has a reputation for durability.

SOLDERING

79. Soldering is the process of joining two metal surfaces together by means of solder. Soldering is done by means of a copper *bit,* sometimes called a *soldering copper* or *soldering iron.* The edges of surfaces to be joined are cleaned and coated with a flux, such as powdered rosin. The copper bit, heated above the melting point of the solder, is cleaned and dipped in the flux. A bar of solder is then held against the end of the bit so that the solder will melt and run into the joint. The hot bit is rubbed back and forth along the joint, to keep the solder liquid, and to guide it into the joint. The solder unites the surfaces of the metal roofing, and forms a solid, metal, water-tight joint. Copper bits weigh from 2 to 8 pounds to the pair, and are used in pairs, one bit being heated while the other is in use. Practically all roof soldering is done by this method.

80. Solders.—Solders are mixtures of two or more metals. When melted, solder adheres strongly to the clean surfaces of certain other metals, and is used to fasten such surfaces together. The solder used for tin roofing consists of tin and lead, the usual proportions being equal parts of each. For this reason the solder is sometimes referred to as half-and-half solder. This solder has a melting point of about 370° Fahrenheit.

81. Fluxes.—Fluxes are used to aid the melting of solder, and to clean the surfaces of metals to be joined. The fluxes commonly used, and the metals to which they are applied, are given in Table III.

TABLE III

FLUXES FOR DIFFERENT METALS

Flux	Metals to be Joined
Rosin	Lead, tin, or tinned metals
Tallow	Lead, tin, or tinned metals
Muriatic acid	Dirty zinc, galvanized metal
Chloride of zinc	Clean zinc, copper, brass, tin, or tinned metals

LAYING TIN ROOFING

82. Preparation of Surfaces. — Tongue-and-groove sheathing boards should be laid under all tin roofs, and the lumber should be dry and well seasoned. Narrow boards are preferable to wide ones, and the boards should be free from holes, and of even thickness. A new tin roof should never be laid over old tin, shingles, or tar roofing. Sheathing felt is not necessary when the boarding is laid carefully, but is desirable on account of its cushion-like effect, in case the roof is ever walked on. If steam, fumes, or gases are likely to be formed in the building, waterproof building paper should be laid over the boarding, to protect the under side of the tin.

83. Methods of Laying Tin Roofing.—There are three forms of laying tin plate for roof coverings, known as *flat-seam roofing, standing-seam roofing,* and *ribbed roofing.*

84. Flat-Seam Roofing.—The flat-seam method, sometimes called the *flat-lock method,* of laying tin roofing, is shown in Figs. 54 to 57. In Fig. 54, the roofing plates are shown attached to the roof by means of nails driven through the edges of the plates, while in Fig. 57 the plates are fastened to the roof by means of cleats, no nails being driven through the roofing tin. The plates, generally 10 inches by 14 inches, or 14 inches by 20 inches in size, are prepared for laying in the main part of the roof by folding under the bottom and left-hand edges of the plate, as at *a* and *b* in Fig. 55, and folding over the upper and right-hand edges, as at *c* and *d*. The width of the edge folded is usually ½ inch, although sometimes only ⅜ inch. These edges are folded in order to form a single lock, as shown at *a* in Fig. 19.

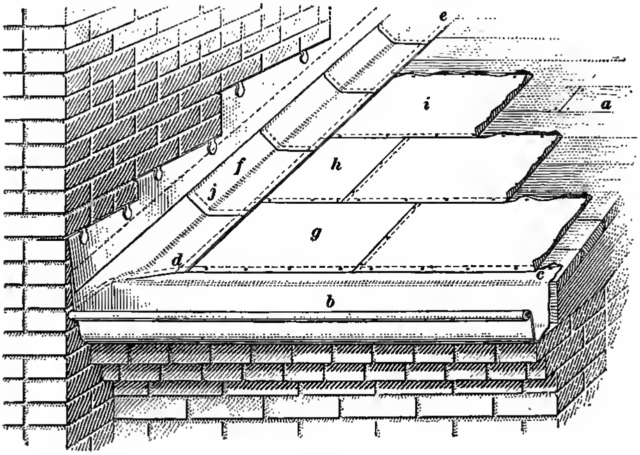


FIG. 54

85. Laying the Roof.—Before a roof, such as is shown in Fig. 54, can be covered with tin roofing, the sheathing *a* and the gutter *b* must be in place. The upper edge of the gutter should be folded over to form a lock, as at *c*, and nailed under the fold, the edge being temporarily raised to permit nailing. The first row of plates *g* is then locked into the gutter, and nailed along the top and right-hand edges of the sheets only. A chalk line *d e* is

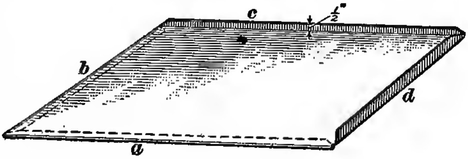


FIG. 55

snapped on the roof about 6 inches from the intersection of the roof and the side wall. This line marks the seam between the plates of the main roof and the flashing *f*. The plates which are laid to this line, as *g*, *h*, and *i*, have the left-hand edge folded up as shown at *a* in Fig. 56, to permit the flashing to be locked properly into it. All the other plates in the main roof are folded as in Fig. 55.

86. The plates are nailed to the roof boarding with 1-inch barbed nails, usually with three nails on the 14-inch side, and two nails on the 10-inch side. The nail heads should never be exposed, as there would be a tendency for the nails to rust and cause leaks.

In starting the second row, a half-plate *h*, Fig. 54, is used in order to break joints. The laying proceeds from left to right, and from the eaves to the highest portion of the roof until the roof is completed to within about 6 inches of the edge of the roof, at which place the tin roofing is left with a folded-up edge to which the flashing may be attached.

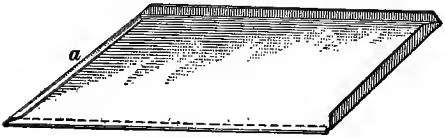


FIG. 56

The method of nailing through the plates should be used only on small areas, as there is no opportunity for the plates to expand or contract without tearing the plates or loosening the nails.

87. The tin flashing is locked into the roofing tin on the line *d e*, Fig. 54, and extends up on the side wall as shown at *f*. The lock in the flashing must be turned so that the water will run over the joint, as shown at *j*, and not against it, as the latter method is almost certain to cause leaks in case the solder fails to hold.

88. A better method of fastening the plates to the roof is by using tin cleats about 1 inch by 2 inches, as shown at *a* in Fig. 57. The cleats are locked over the upper and right-hand edges of the plates *b*, and nailed to the roof as shown at *c*, usually with two 1-inch barbed nails. The end of the cleat should be folded back over the nail heads as at *d*, and as shown at *a* in Fig. 58, so as to prevent the nail heads from scratching and damaging the surface of the tin. When cleats are used to hold the plates, the roofing may contract with the cold or expand with the heat, and the strain will be on the cleats, not on the seams, as in the case when the nails are driven through the edges of the plates.

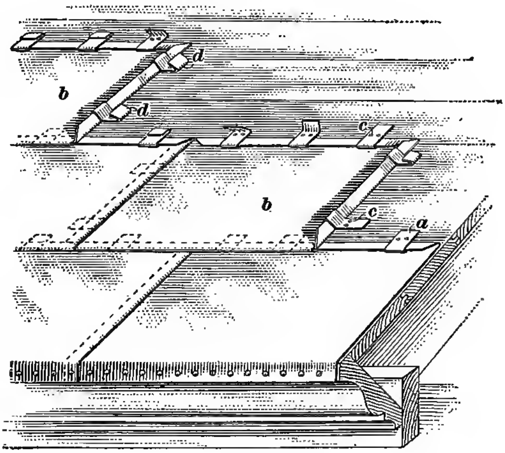


Fig. 57

89. The roofing tin may be brought to the job in rolls, in which the plates have the cross-seams locked together and well soldered in the shop. The roll is cut into suitable lengths and the edges are turned to lock into the adjoining strips. Cleats are placed along the side of the strip at 8-inch intervals, in the manner just described. This method reduces the labor on the job, both for laying the tin, and for soldering the seams. The strips may run across the roof parallel to the

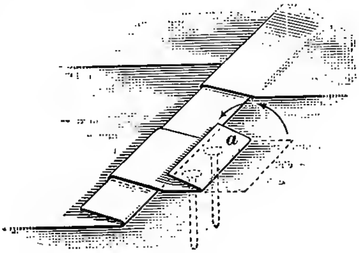


Fig. 58

eaves, or they may be placed from the eaves to the ridge or higher portion of the roof.

When all the roofing tin is in place, the seams between the plates are pounded down with a wooden mallet, and are soldered with half-and-half solder, rosin being used as a flux.

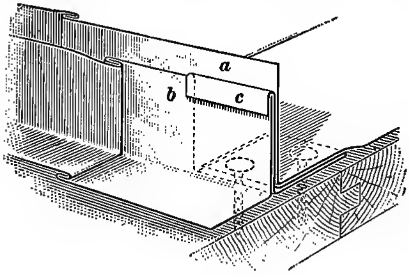


Fig. 59

90. Standing-Seam Tin Roofing.—Standing-seam tin roofing, sometimes called *roll-tin roofing,* can be used when the pitch is 2 inches or more to the foot. The roofing is brought to the job in rolls, similar to roll roofing already described, and is laid in the same manner. The cross-seams are double-locked usually, as at *a* in Fig. 20. The single-lock seam, as shown at *a* in Fig. 19, is always soldered, while the double-lock seam is sometimes left without soldering. This latter method should only be used with roofs of considerable pitch, however, as the seam is not tight, and there is a possibility of leaks occurring if the roof is nearly flat.

When the length of the strips necessary to reach from the eaves to the ridge is known, the strips can be made of that length in the shop, so as to save time and labor on the job.

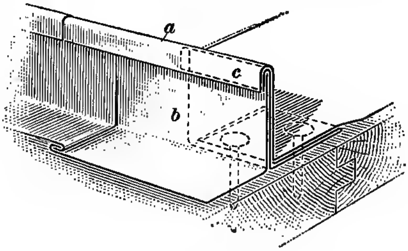


Fig. 60

91. The roofing may be painted on one or both sides before laying, as the cross-seams are soldered in the shop, and the standing seams do not require soldering. Painting on the under side is advisable in any case.

The strips after being cut to the proper length have the edges turned up to form the side seams. The left-handed edge is turned up $1\frac{1}{2}$ inches, and the right-hand edge $1\frac{1}{4}$ inches, as shown at *a* and *b* in Fig. 59. These strips are held in place by cleats *c*, placed not more than 12 inches apart. The higher edge *a*, with the top of the cleat, is first bent over the lower edge of the adjacent strip, as shown in Fig. 60. The turned-over portions are again bent down as shown in Fig. 61, and finally folded tight, as in Fig. 62, making a double-lock seam about 1 inch high. Fig. 63 shows a portion of a completed roof, with the side and edge left unfinished, to show the method of applying the cleats and laying the roofing. It may be noted that this method is similar to double-lock standing-seam roll roofing.

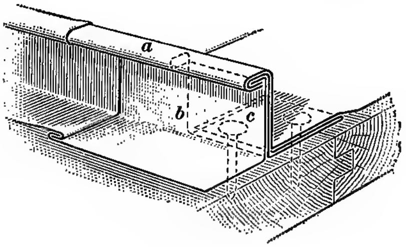


Fig. 61

The standing seam in Figs. 59 to 63 is shown folded over to the left. The seam might equally well be folded over to the right, by bending up the right-hand edge of the sheet the greater distance, and working from left to right across the roof. Each course should be finished before starting the next.

92. The lower edge of the strip is locked into the gutter or eaves flashing, in the same manner as described for flat-seam roofing. At the ridges the upper 5 or 6 inches of the standing seam is flattened down to the roof surface, and the sheets from the adjoining roof surface are then locked into the first sheets, as in Fig. 36. The finish at the ridge may be the same as the standing seam of the roof, by allowing the strips to pass the center of the ridge enough to flange up 1½ inches on one side and 1¼ inches on the other, the seam being turned in the same manner as described for

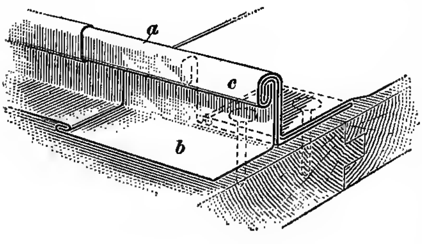


Fig. 62

the standing seam on the main part of the roof. If a ridge roll is to be used, only $\frac{1}{2}$ inch need be allowed for an overlap.

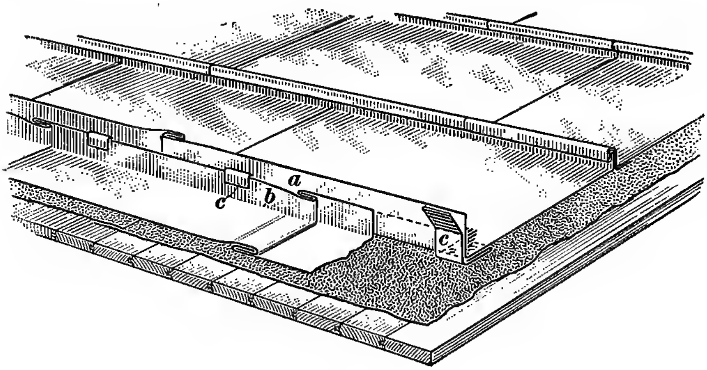


FIG. 63

Hips are usually finished the same as the ridge, after cutting off to the proper angle.

93. Ribbed Roofing.—Tin plates may be used for roofing on pitches steeper than 2 inches to the foot, by the use of wood ribs, as shown in Figs. 64 to 69, in which the same reference letters are used for the corresponding parts. The ribs may be placed for architectural effect, or they may be placed to suit the width of the roofing plates.

94. The roof should first be covered with building or sheathing paper *a*, Fig. 64, free from tar or acids. Over this are placed wood ribs *b*, which are about 2 inches by 2 inches in size, and spaced $17\frac{3}{8}$ inches on centers for tin 20 inches wide. The tin strips *c* and *d*, Fig. 65, are bent up on both sides so as to stand $\frac{3}{8}$ inch above the top of the ribs. The strips should fit loosely between the ribs, especially when the roof is laid in the winter months, so as to allow for expansion. The edge is then bent over as shown at *d*, ready to receive the cap. Tin cleats *e* and *f*, Fig. 66, one for either side of the rib, are locked over the bent-over edges,

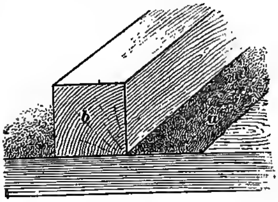


FIG. 64

and then nailed securely to the top of the rib. The ends of the cleats are turned over the nail heads, as at *g*. The cleats are usually spaced 8 or 10 inches apart along each side of the rib.

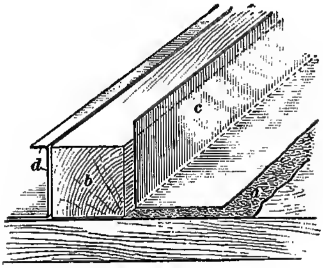


FIG. 65

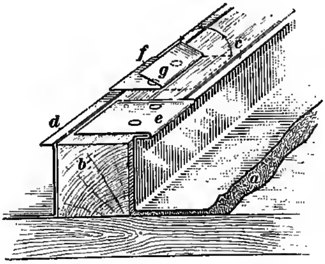


FIG. 66

95. A cap *h*, Fig. 67, is cut $3\frac{3}{4}$ inches wide, allowing $\frac{3}{8}$ inch on each side to turn under. One side is turned as far as possible, as at *i*, the other turned square, as at *j*. The sharp-turned edge *i* is hooked over the edge of the tin, the side *j* then being pressed down and turned under. Both sides are then turned against the side of the rib snugly, as at *i* and *j*, Fig. 68, thus completing the joint. An enlarged section of a portion of the finished rib at a cleat is shown in Fig. 69. The end of the rib *b* may be covered with a piece of tin with the lap turned out on all sides, and finished the same as the cap. Roofs laid in this manner, not being soldered, should have a good pitch.

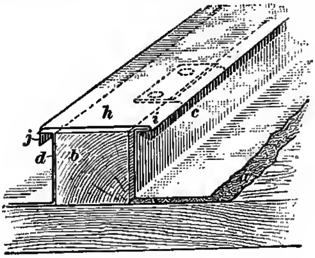


FIG. 67

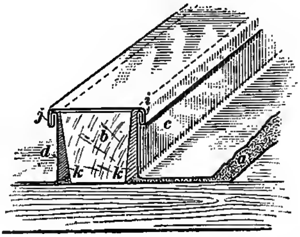


FIG. 68

96. The shape of the rib may be varied for architectural effect or appearance, and the cleats may be fastened to the sides of the ribs if desired. The rib is sometimes made with sloping sides, so as to be narrower at the roof surface than at the top of the rib, as at *k* in Fig. 68, to allow for expansion.

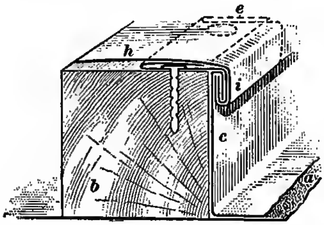


Fig. 69

97. While it is always cheaper in the long run to use the best material, roofing plates with a lighter coating may be used for steep roofs. IC plates in which the iron body weighs 50 pounds to the square, are more suitable than IX plates having a weight of 62½ pounds, because the seams in the lighter plates will not suffer so much from contraction and expansion as will those in the thicker plates.

98. Flashings for Tin Roofs.—Tin roofs are flashed against brick walls, chimneys, fire-walls, gables, and the like, by extending the roofing material up about 6 inches on the wall as shown in Fig. 70, and counterflashing with tin. The roof boards *a* are first covered with felt or paper *b*, which extends up on the wall as shown. The roofing tin is laid as at *c*, and the flashing tin *d* is locked into it at *e*. In every case the lock

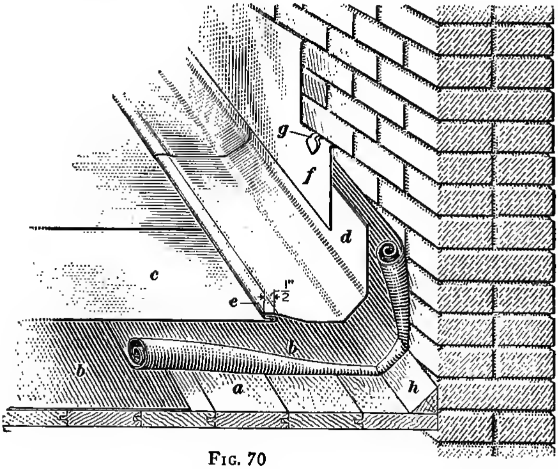


Fig. 70

must be turned away from the wall, so that the water will not flow against the seam. The counterflashing *f* extends to within 2 inches of the roof surface, and the upper edge is let into the joint in the brickwork 1½ inches, being held in place by wall hooks, as at *g*. The brick joint is afterwards filled with mastic cement. A triangular fillet strip *h* permits an easy bend of the flashing at the corner between the roof and the wall.

99. When abutting against a wooden wall, the roof tin should be turned up against the boarding, and the wall covering of siding or shingles should be laid over it down to within 2 inches of the roof.

Flashings for wooden skylight curbs, bulkheads, scuttles, and other roof openings may be formed as shown in Fig. 71. The curb flashing *a* is nailed to the top of the curb *b* at *c*, and turned down against the curb, over the fillet *d*, and is locked into the roofing at *e*. The figure shows a scuttle, the cover *f* being covered with metal *g*.

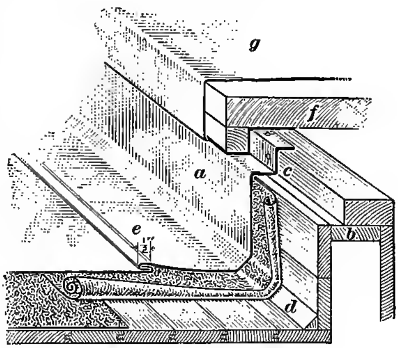


Fig. 71

100. Amount of Tin Required.—Sheets 10 inches by 14 inches, and 14 inches by 20 inches, are generally used for roofing purposes. The smaller size is to be preferred generally, because the larger number of seams stiffens the surface and helps to prevent buckling and rattling in stormy weather. The cost, however, is increased somewhat because more work, solder, and materials are required.

Measurements in tin roofing are based on the square of 100 square feet, as in other forms of roofing. Hips, valleys, and flashings are measured by the linear foot, as are also gutters, and leaders, or conductors.

101. One sheet of tin 14 inches by 20 inches covers 247 square inches when folded with ½-inch edges all around, or about 192 square feet to the box of 112 sheets. If laid with ⅜-inch folds, each sheet will cover 255 square inches, a box covering about 198 square feet.

When used for standing-seam roofing, one sheet of 14″×20″ tin covers 224 square inches, and a box of 112 sheets covers about 174 feet of roof, allowing 1 inch and 1¼ inches for the two side seams, and ⅜-inch single locks for the top and bottom seams. In these calculations, no allowance is made for waste of any kind.

102. Roof Painting.—Roofs and sheet-metal work should be kept well painted, the intervals between the coats depending largely on climatic conditions, being usually from 3 to 5 years. After an initial coat of red-oxide paint ground in linseed oil, the roof can be painted any shade or color to conform to a given color scheme.

COPPER ROOFING

103. Properties of Copper.—Copper is distinguished from all other metals by its peculiar red color. This color changes after the copper has been exposed to the atmosphere for some time and becomes a light green. Copper is very malleable, ductile, and tenacious, and it expands and contracts with the temperature more than other metals commonly used for roofing. The resistance of copper to corrosion when exposed to the atmosphere, combined with its lightness, gives it great value for use as a roof covering, and for flashings in connection with other roofing materials, such as slate, tile, and composition.

104. Sheet Copper.—Copper may be obtained in sheets, cut to market sizes varying from 24 inches by 48 inches to 48 inches by 96 inches. Sheet copper is supplied in two forms; soft, or annealed; and hard, or cold rolled. Both forms may be tin coated, or tinned, on one or both sides, or on the edges, when required. Tinning is resorted to so that the solder may flow, or sweat, more freely than it will on bare copper. Half-and-half solder is used for copper roofing, the same as for tin roofing.

Copper is usually specified as weighing so many ounces to the square foot. The weights and thicknesses of copper used for roofing are given in Table IV.

105. Laying Copper Roofing.—Copper roofing is laid in the same manner as the roofs already described. The flat-lock roof is not to be commended, however, except for small areas, as, being soldered and nailed, there is not sufficient provision for expansion and contraction, which is considerable with copper. Either the standing-seam or the ribbed method may be employed, the ribs often being made to form an ornamental roof.

TABLE IV

WEIGHT AND THICKNESS OF SHEET COPPER

Weight, Ounces to the Square Foot	Thickness in Decimal Parts of an Inch
10	.0134
12	.0161
14	.0188
16	.0215
18	.0242
20	.0269

106. Flashings for Copper Roofs.—Flashings and counterflashings for copper roofing should be of copper. Owing to the similarity of the sheets of copper to the sheets used for other forms of roofing already described, the methods of flashing described under tin roofing and sheet-iron and steel roofing may be followed with copper roofing. On account of the expansion and contraction of copper, the connections between the roofing and the gutters and valleys should be double-locked, and to permit free movement they should not be soldered.

ROOFING

(PART 2)

KINDS OF ROOFING—(Continued)

WOODEN SHINGLE ROOFING

MANUFACTURE OF WOODEN SHINGLES

1. Wood Used.—Shingles are made principally from *cypress, cedar,* and *redwood.* Small quantities of shingles are also made from *white pine, spruce,* and *hemlock.*

Cypress is a wood of great durability, and is particularly adapted for use in the form of shingles, as it will not curl or split under ordinary conditions.

California redwood makes durable shingles and has the advantage of being less inflammable than other woods. It is also soft and resists the tendency to rot for many years.

Cedar, both white and red, is used very extensively for making shingles and is very durable. The red cedar, or giant arbor vitæ, of the Pacific coast, is manufactured extensively into shingles. Because of the general straightness of the grain, red-cedar shingles are not roughened by exposure to the sun, as are shingles made of other woods, and therefore offer a better weather-resisting surface.

2. Size of Shingles.—The lengths of ordinary shingles are 16 inches and 18 inches. Special shingles are made 27 inches or more in length. The width of shingles varies

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from 2 inches to 16 inches. Shingles are wedge shaped, tapering in thickness from the butt to the top. The thickness at the butt varies in different grades of shingles, from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch, and is sometimes stated as the number of butts in a given number of inches, as 5 butts to 2 inches, 20 to $8\frac{3}{4}$, 25 to $7\frac{3}{4}$, etc. The top or upper end of the shingle is about $\frac{1}{16}$ inch thick.

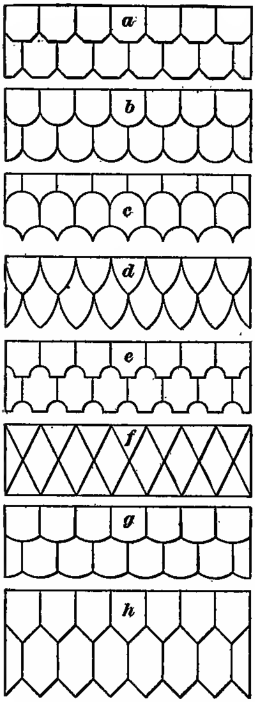


Fig. 1

3. Manufacture of Shingles.—Shingles are generally sawed but may be split. The sawed shingles are cut in a wedge shape. The split shingles are split from a block of wood, and then shaved with a draw knife to the desired tapered shape. These shingles, known sometimes as shaved shingles, are made only in a few localities, and vary considerably in width, thickness, and length. Split shingles are called *shakes* in some localities. Practically all shingles have rough surfaces, just as they come from the saw, although some grades are planed on one side.

4. Dimension shingles are cut to a uniform width with square butts, and are used to obtain a uniformity of effect. They are made 4, 5, and 6 inches in width and may be obtained in practically all the woods used for shingles.

5. Fancy butts, or **pattern butts,** are shingles of uniform width having the butts sawed to geometric forms. Some of these forms are shown in Fig. 1, in which *a* is the *octagon* patetrn; *b*, the *round; c*, the *cove point; d*, the *gothic; e*, the *cove corner; f*, the *diamond; g*, the *segment;* and *h*, the *hexagon.* Combinations of these patterns may be used to give other designs, for either roof or wall surfaces.

6. Packing Shingles.—Shingles are packed for sale in bunches, or bundles, each bundle containing the equivalent of two hundred and fifty shingles 4 inches wide. Four bundles, containing the equivalent of one thousand 4-inch shingles are taken as the unit of measurement. Certain makes of dimension shingles are packed in bundles containing fifty shingles regardless of the width.

7. Ready-Stained Shingles.—Shingles are sold that have been dipped in a creosote preservative and colored. This treatment adds to the durability of the shingles and gives them a color effect when laid on the roof.

8. Grading Shingles.—Shingles are sold according to grading rules that differ with the kinds of wood used. Thus, the grades of western red-cedar shingles are 24″ Royals, 18″ Perfections, 18″ Eurekas, 16″ Perfects, 16″ Extra Clears, 16″ Extra Star-A-Stars, etc., the Royals being the best, and the others permitting more and more defects in the order named. The grades for northern white-cedar shingles are given as Extra Star-A-Stars, Standard Star-A-Stars, and Sound Butts. The grades for cypress shingles are Bests, Primes, Star-A-Star, Economy, and Clippers.

Shingles having the exposed surface free from defects are generally known as Clear Butts.

PREPARATION OF ROOF SURFACES

9. Pitch of Shingle Roofs.—Roofs to which shingles are to be applied should have a pitch of not less than 6 inches to the foot, or what is known as a ¼ pitch. Shingles are adapted for use on any pitch steeper than this. They are frequently used as a siding for walls in frame homes.

10. Roof Surfaces.—Shingles may be laid on a surface that is boarded over, as at *a* in Fig. 2, or upon *shingle lath,* as shown at *a* in Fig. 3. The boards are laid horizontally, as shown in Fig. 2, and should be matched. The boards used are 1 in.×4 in., or 1 in.×6 in. In some cases the boards are

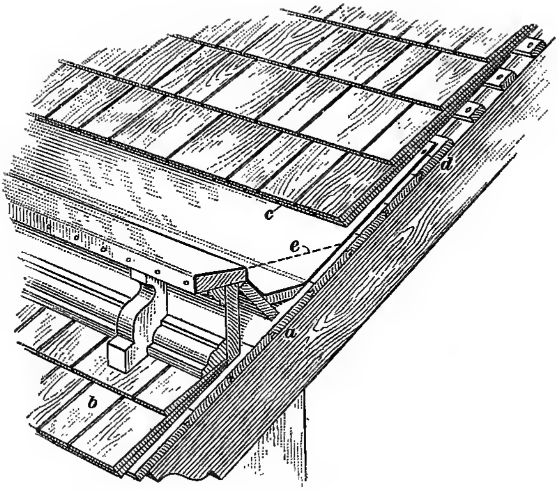


FIG. 2

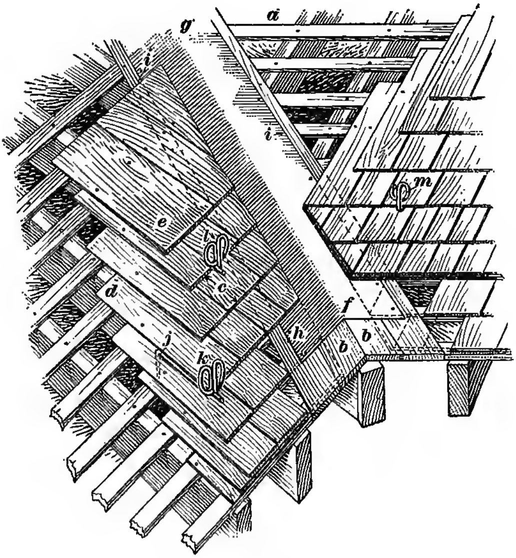


FIG. 3

laid with a space of 1 or 2 inches between them, as shown in Fig. 4, in which case they need not be matched. In very cold climates, such as in parts of Canada, the roofs are laid tight with matched boards and covered with building paper before the shingles are laid.

11. The shingle lath, illustrated at *a* in Fig. 3, consists of strips of wood about 1 in.×2 in., or 1¼ in.×3 in., in cross-section. They are spaced at a distance on centers equal to the exposure of the shingle or about 4 or 4½ inches, thus providing nailing for each row of shingles, as shown in the figure. The use of shingle lath is considered desirable, as it allows for ventilation of the under sides of the shingles, which prevents their rotting.

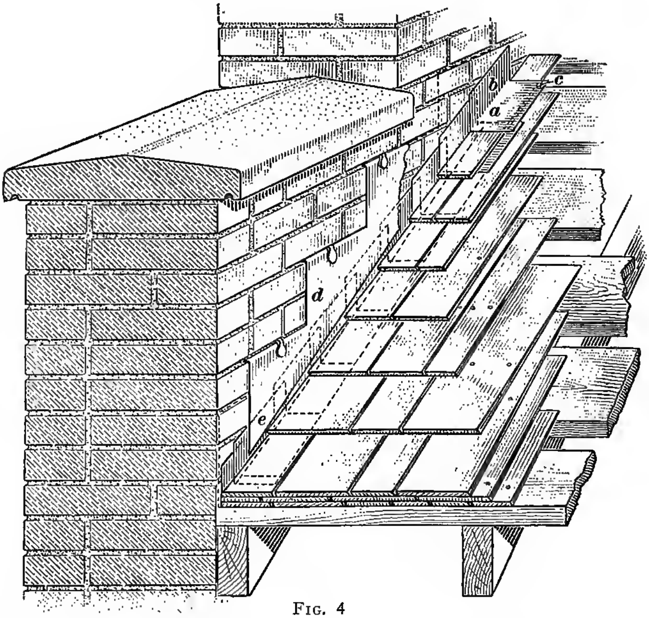


Fig. 4

12. When shingle lath or boards with spaces between them are used, the first 8 or 10 inches above the eaves, as well as the part of the roof that projects outside of the walls of the building, should be covered with tight boarding. This will protect the shingles should it become necessary to walk along the eaves in making repairs. Boards should also be laid at the ridge for at least 6 or 8 inches on each side, to afford good nailing space for the top courses of shingles and the ridge finish.

Valleys should be boarded for at least 10 inches on each side, as shown at *b* in Fig. 3, to receive the flashing of the valley.

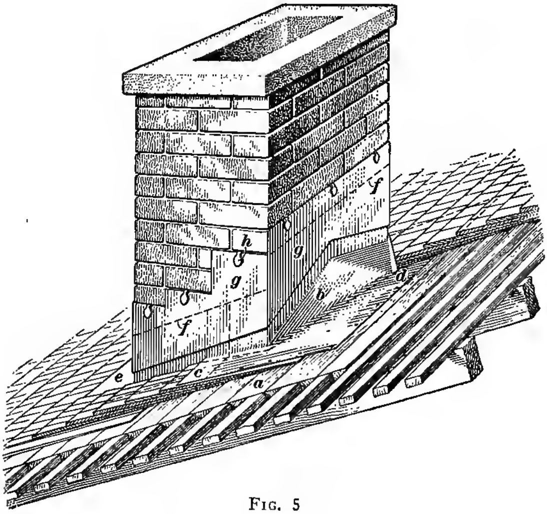


FIG. 5

It is also advisable to board on each side of the hips to provide a good surface for nailing the shingles and any flashings that may be used.

13. Around all chimneys, ventilators, skylights, and similar constructions that project through the roof surfaces, the roof should be boarded solid for 12 to 16 inches on all sides, so as to take the necessary flashings. At the backs of chimneys and other constructions that interrupt the flow of water, saddles should be constructed and boarded solid so as to pitch the water to the sides of the obstacle. In Fig. 5 the boarding on the roof around a chimney is shown at *a* and a saddle at *b*.

14. Method of Finding the Gauge.—The *gauge* of a shingle is the length of the shingle that is exposed to the weather, as at *c*, Fig. 3. It is customary to have at least three thicknesses of shingles covering every point of the roof. It is also the rule that the tip of the shingle shall extend under the third shingle above it $1\frac{1}{2}$ to 3 inches. Thus, under each butt there are three shingles. This may be seen clearly in Fig. 3. The tip *d* of one shingle extends up under the butt *e* of the third shingle above it. This $1\frac{1}{2}$ to 3 inches is called the *lap*.

The gauge of a shingle equals the total length of the shingle less the lap, divided by three. If the shingle is 16 inches in length and the lap is $2\frac{1}{2}$ inches, the gauge is $(16-2\frac{1}{2})\div 3 = 4\frac{1}{2}$ inches. If the shingle is 18 inches in length, and the lap is 3 inches, the gauge is $(18-3)\div 3=5$ inches.

The gauge may be determined first, but must not be too large to permit of a suitable lap. Thus, the gauge of a 16-inch shingle should not exceed 4 or $4\frac{1}{2}$ inches, in order that the lap shall be 3 inches, or $2\frac{1}{2}$ inches.

15. Number of Shingles Required.—The gauge decided upon determines the number of shingles that will be required for a square of roofing. Thus, if the gauge of a shingle is 4 inches, and the average width is 4 inches, the total exposure is 16 square inches. The area of a square of roofing is 10 ft.×10 ft.=100 sq. ft.×144=14,400 sq. in., and 14,400÷16=900, which is the number of shingles that will be required for a square of roof surface.

An allowance should be made for cutting and waste. Ten per cent. is sufficient for simple roofs, but more should be allowed upon roofs that are cut up with hips, valleys, and dormers. The greater the gauge, the smaller the number of shingles that will be required, and the smaller the gauge, the larger the number of shingles that will be required.

16. Laying Shingles.—The starting courses of shingles should be doubled, as shown at *b* and *c*, Fig. 2. In very careful work these courses are sometimes tripled. Doubling them is necessary so that the joints in the under course will be covered. The butts of the shingles *b* should extend beyond the roof boarding for about 1 inch to form a drip.

The line of butts should be made straight and true. The length of the gauge is laid up from these butts at each end of the course, and marks made. Between these marks a chalked line is stretched and snapped, thus making a true line to which the shingles of the next row are laid. This line will be referred to as a *gauge line*.

Each shingle is nailed with two fourpenny nails, so that the nails will enter a lath as shown in Fig. 3. The nails are driven so as to be covered by the next course of shingles, and should be of zinc or galvanized steel, as plain steel or wire nails will soon rust, and the shingles will drop out. The shingles in each course should break the joints with the course below, and the nail heads should not be directly under the joint.

17. If the shingles are dry when laid they should be kept about $\frac{1}{4}$ inch apart, to allow for expansion when they are wet. If the shingles are wet, they should be laid close together. When dry they will naturally shrink and draw away from each other. Some contractors wet the shingles before laying them so that the shingles will attain their maximum width. They can then be laid close together with safety. A space between the shingles allows the water to drain off rapidly, dries the roof quickly, allows for expansion, and prevents buckling. The shrinkage and the expansion are small with narrow shingles, and correspondingly larger with wide ones. Shingles over 7 inches in width should be cut in two to prevent shrinkage and possible splitting of the shingle.

18. Ornamental Shingling.—Dimension shingles, and especially those with fancy butts, as shown in Fig. 1, are used to obtain a varied effect on the roof, or on the shingled sides of a building. Fancy butts should be used rather sparingly, lest the effect be spoiled, and they probably are best used in horizontal bands of 6 to 15 courses, depending on the location and size of the roof or surface shingled.

19. Common shingles may be laid with the butts uneven, varying an inch or more alternately above and below the true gauge line. This gives an irregular effect, and relieves the monotony of straight lines. Another pleasing effect is obtained sometimes by doubling every fourth, fifth, or sixth course of shingles. Still another method is to lay the alternate courses with different gauges, such as 4-inch and 1-inch, or 5-inch and 2-inch. A variation of the latter method is to lay the lower courses with the wider shingles and at a greater gauge, and to decrease the width of the shingles and the gauge toward the ridge.

20. Stained Shingles.—Shingles may be stained in various colors to harmonize with the color scheme of the house. For this purpose either oil or creosote stains are used, but paint is to be avoided, as it destroys the texture effects of the grain of the shingle. Shingles may be dipped two-thirds their length in the stain, or brushed on one side only; the latter is, of course, more economical, but is not so lasting. Stained shingles should be dried thoroughly before they are laid and should be spaced $\frac{1}{4}$ to $\frac{3}{8}$ inch apart when laid, to provide for expansion.

21. Open Valleys.—An open valley is illustrated in Fig. 3. In this valley the shingles are kept several inches apart, exposing the sheet-metal flashing. The water will run down on the metal surface. In laying an open valley, lines should be snapped, with a chalked line, parallel to the bend *f g* in the flashing, and the shingles should be cut to the chalk line. So far as possible, the shingles should be nailed so that the nails do not penetrate the flashing. The flashing should extend under the shingles for several inches, as shown at *h*, and should be nailed only at the edges as at *i*.

22. Close Valleys.—A close valley is illustrated in Fig. 6. In this figure the shingles are shown interwoven with sheets of metal flashing *a*. These metal sheets are cut to a pattern and bent. One sheet is laid over each course of shingles and under the top layer of shingles. This conceals the flashing except in the valley between the shingles. The valley is about $\frac{1}{2}$ inch in width.

The general manner of covering this valley is as follows: A row of shingles is laid on each side of the valley as at *b*, Fig. 6. A clear space of $\frac{1}{2}$ inch is kept between the edges of the shingles, as shown. The gauge lines are then made and the sheet of metal is laid so that the lower edge is slightly above the gauge lines. The next course of shingles is then laid, and covers the metal except the $\frac{1}{2}$ inch in the valley.

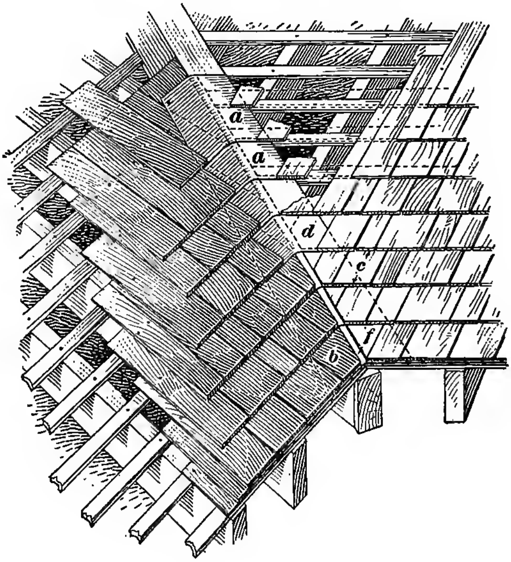


Fig. 6

The gauge *c* is then laid off and another piece of flashing, as at *d*, is set slightly above the gauge line. The next course of shingles covers this metal except the $\frac{1}{2}$-inch space. This process is repeated until the valley is completed. This produces a tight valley and is used more on account of appearance than durability. Snow and rain are likely to keep the shingles damp, and thus cause them to rot before the rest of the roof.

23. Laying Hips.—Hips may be laid by lapping the edge of one shingle over the edge of the shingles on the adjacent side of the roof, as illustrated in Fig. 7. Such a finish, however, is not the most durable. This finish can be made water-tight by the use of sheet-metal flashings *a* which are woven into the shingle work as shown. The flashing is cut to a pattern and laid just before the covering rows of shingles *b* and *c* are put in place.

24. Boston Hips.—The finish shown in Fig. 8, known as the *Boston hip*, is very effective and neat. Under ordinary conditions it is sufficiently weather-tight for all purposes. Shingles of a uniform width, such as 5 inches, should be selected. A chalk line is snapped on each side of the hip about 4½ inches from it and parallel to it, as at *a–a* and *b–b*.

A guide line *c–c* is also struck down the hip line to keep the finished hips true. The shingles of the courses, as at *d* on the roof slopes, should be carried so that the butts *e* finish against the lines *a–a* and *b–b*, and should be mitered together on the lines *c–c*, as shown at *f*. The first hip shingle *g* is laid with the sides of the shingles in touch with the lines *a–a* and *b–b*, and the lower corner of the butt just touching the butts of the shingles below, as at *h*. The tops of the hip shingles are fitted against the side of the main-roof shingles, as shown at *i j*, and nailed in place. The edge *j k* of the hip shingle *l* is cut so

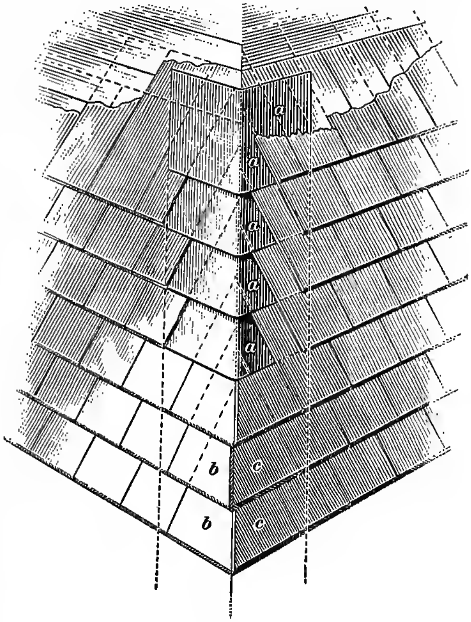


Fig. 7

as to be in the plane of the right-hand slope of the roof, so that the shingle *m* will lie flat upon it. After the shingle *m* is laid, its edge *j k* is cut so as to be in the plane of the left-hand slope of the roof. This forms a finish of pleasing effect, and furnishes a substantial protection to the hip. The addition of flashing, such as shown in Fig. 7, will add to the tightness of the joint, but is not, as a rule, necessary.

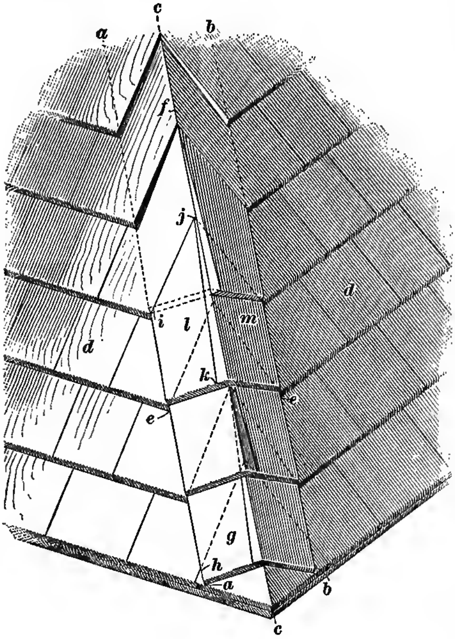


FIG. 8

25. Finish of Ridges.—One method of finishing a ridge of a shingle roof is to cover the ridge with ridge boards *a*, Fig. 9. The boards are lapped as shown, and the upper board is nailed firmly into the edge of the other board. This forms a fairly substantial finish.

Another finish consists of putting the wooden roll *b*, Fig. 9, over the joint of the ridge boards, and nailing it securely. This adds somewhat to the durability of the ridge finished in plain boards.

A third method consists of adding a sheet-metal covering *c*, Fig. 9, which is formed to cover the roll and the boards. The metal is nailed as shown at *d*. This method forms a tight and durable finish.

26. Shingling Conical Roofs.—For covering conical roofs, the shingles should be selected in three or four widths, the widest being 5 inches, for laying at the eaves, and the

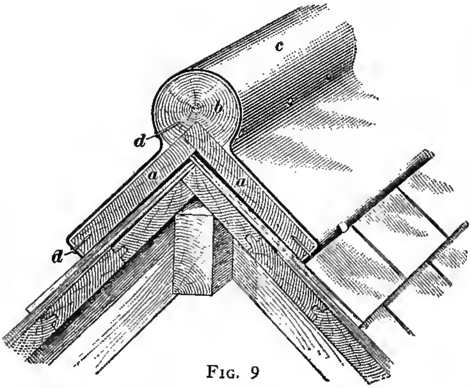


FIG. 9

narrowest being 2 inches, for the top of the roof, as shown at *a, b, c,* and *d,* in Fig. 10.

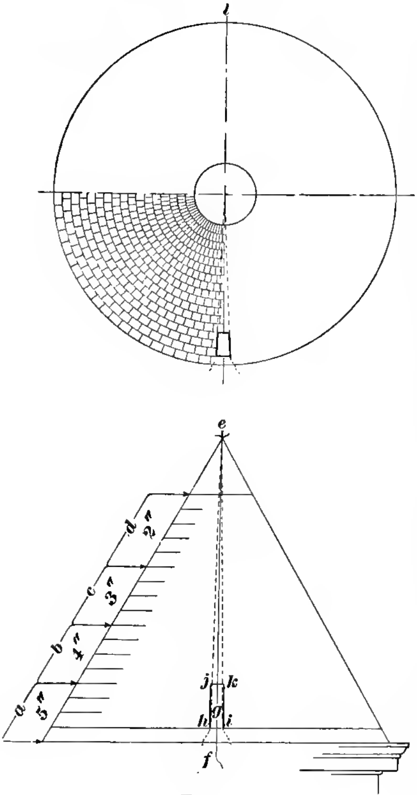


FIG. 10

To keep the shingles true to radial lines, and the butts in line with the horizontal curves or courses running around the tower, a nail is driven into the center of the apex post *e,* to which a cord *f* is attached. The starting course is laid horizontally with the eaves, the next gauge is laid off, and a shingle *g* is tacked in place. The cord is held to a joint of the first course under the tacked shingle, and a line is drawn through the center of the shingle *g* vertically. The cord is then moved to the outside corner of the butt, first on one side *h,* and then on the other side *i.* The side or taper lines *h j* and *i k* drawn in this manner will be radial to the center of the apex, as shown by the plan. A shingle cut to the lines marked will form a templet for all the shingles of the first course. The shingles with 5-inch butts should be laid first, then the 4-inch, and so on until each lot is used, making a new templet for every course.

This mode of application should be continued until the base of the finial is reached, when, if a wooden cap is to be used, the apex should be flashed with metal. If, however, a sheet-metal finial is used, the flashing may be omitted.

FLASHINGS FOR SHINGLE ROOFS

27. Materials Used.—The materials commonly used for flashings on shingle roofs, together with their thicknesses, are as follows: IX tin, No. 26 galvanized iron, No. 9 zinc, and 16-ounce copper. The choice will depend on the cost and durability as well as on the availability of the materials. For the flashings already described in connection with shingle roofing, any of these materials may be used.

28. Flashing Against Parapet Walls.—When a shingle roof abuts against a parapet wall, the roof is flashed as shown in Fig. 4. Metal sheets *a,* about 7 inches square, are folded so as to extend out on the roof about 3½ inches, and up on the wall the same distance, as at *b*. The sheets are nailed as at *c*. The flashing is covered by a counterflashing *d,* the lower edge of which reaches down almost to the shingles, as at *e*.

29. Flashing at Chimneys.—At chimneys and similar projections through the roof, the flashings should extend 3 or 4 inches under the shingles at the sides, as at *c* in Fig. 5. At the back, the flashing *d* should be wide enough to receive the saddle *b,* and also extend up under the shingles 3 or 4 inches. The flashing *e* at the front of the chimney should extend over the tops of the shingles for a distance equal to the gauge of the shingles.

The saddle, which is formed of boarding, is covered with the same metal as is used for the flashing.

The flashing should extend up against the vertical surface of the chimney for 4 or 5 inches, except over the saddle where it extends up for a distance of about 5 inches above the highest point of the saddle. The broken lines *f*, Fig. 5, show the top lines of these flashings. These flashings are nailed to the roof only and not to the chimney.

A counterflashing *g*, Fig. 5, is let into the joints of the brickwork, and secured in position with the nails *h*. It extends down over the flashing to within 2 inches of the shingle roof.

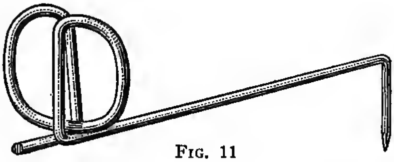


FIG. 11

30. Flashing at Gutters.—In Fig. 2 is illustrated a method of flashing a gutter that is built up on a roof. This flashing is a continuation of the gutter lining, and extends up under the shingles a distance of 8 or 9 inches as at *d*. The butts of the shingles should be placed well above the top of the gutter, which is shown by the broken line *e*.

31. Snow Guards.—Snow guards made of various forms are used on pitched roofs to prevent masses of snow from sliding down into the gutter or off the roof. They also hold the snow in place until it can melt and run off. These guards are generally made of galvanized iron or copper wire, and are of such shapes as to fit into the roofing construction. Generally two or three rows are placed near the eaves while occasionally guards are spaced over the entire surface of the roof.

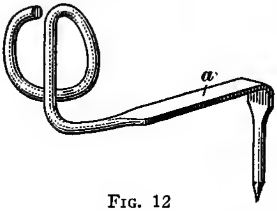


FIG. 12

In Fig. 11 is shown a style of guard that is used with either shingle or slate roofing. The guard is set between the edge joints of the shingles or slates, as shown at *k* in Fig. 3, and the point of the guard, shown at *j*, is driven through the shingle and into the shingle lath. The guard extends down past the butt of the overlapping shingle, and the raised portion projects above the surface at this point, as at *k*. Other guards are shown at *l* and *m*.

A guard of similar construction to that in Fig. 11 is shown in Fig. 12. This guard has a shank *a* flattened down to the thickness of a shingle or slate, which allows the overlapping shingle or slate to lie flat on the roof.

METAL SHINGLES, SLATES, AND TILES

GENERAL DESCRIPTION

32. Sheets of metal are stamped into various shapes as shown in Fig. 13, in which (*a*) is a *metal shingle*, (*b*) is a *metal slate*, and (*c*) is a *metal tile*. These sheets are used in place of shingles, slate, tile, and other roofing. They are designed to be locked into each other and to be nailed on a roof that is boarded all over. Being of thin metal they are very light in weight. They are also incombustible and prevent a building from catching fire through the roof.

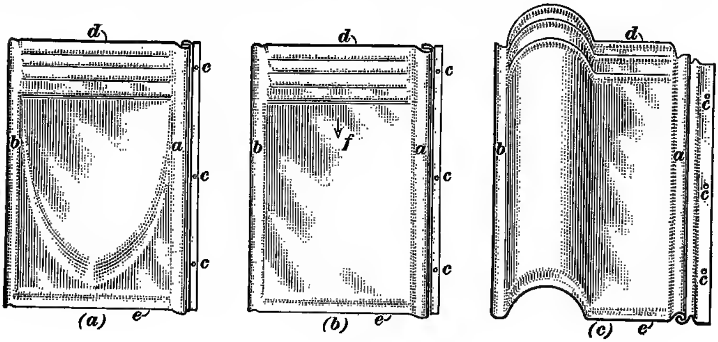
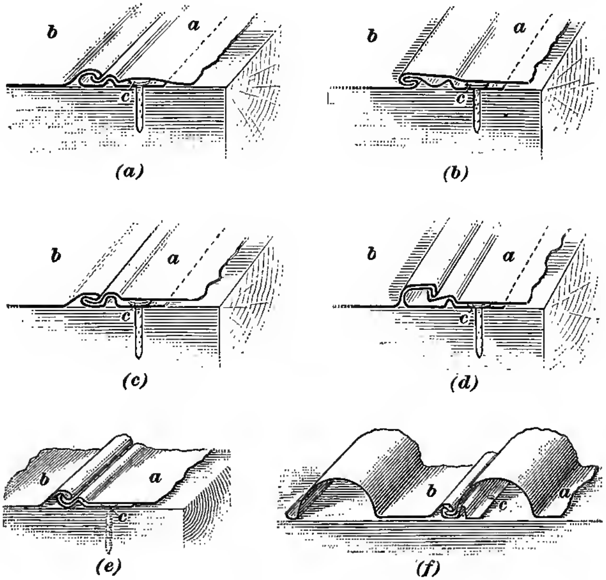


FIG. 13

33. Manufacture.—These roofings are made by pressing or stamping sheets of metal into the desired shapes. They are made in a variety of styles, shapes, and sizes, each manufacturer varying the form and ornamentation so as to make his product distinctive. In making these roofings, the pressing or stamping not only forms the design and the embossing of the piece, but also forms the lock-joints at the sides and at the ends.

The usual shape of metal shingles, slates, and tiles is rectangular, and while there is a variety in size, the most common sizes are made of metal 7 inches by 10 inches, 10 inches by 14 inches, and 14 inches by 20 inches in size. For one square of roofing there will be required from 300 to 320 pieces of the 7-inch by 10-inch size; from 140 to 148 of the 10-inch by 14-inch size, and from 65 to 85 of the 14-inch by 20-inch size. The difference in the covering ability of the same size is due to the difference in the design of the lock-joints, some joints requiring more metal than others.

The sides are designed to lock together and make a tight joint through which water cannot pass. Several designs for joints of this kind are shown in Figs. 13 and 14, which will be described later. The butt of the piece above sets down over the top of the piece below, and the butts and tops are designed to prevent water from being blown up between the shingles by the wind. Examples of these joints are shown in Figs. 13 and 15.



(a) (b) (c) (d) (e) (f)

Fig. 14

34. Details of Joints.—In Fig. 13 at *a* and *b* in (*a*), (*b*), and (*c*) are illustrations of locking joints, the edges *b* being inserted in the grooves at *a*, and the shingle being nailed at *c*. In Fig. 14 are shown several designs for side joints that are used in connecting these shingles, slates, and tiles. Those lettered from (*a*) to (*e*) inclusive are applicable to metal shingles and slates. The one shown in (*f*) is used with the metal tiles. In these illustrations it will be seen that the edge of the sheet *a* locks into the plate *b* so that a tight joint is formed. These joints are also designed to permit of expansion and contraction, without opening the joint. The nails *c* are also covered and protected by the overlapping edge of the adjacent shingle or slate.

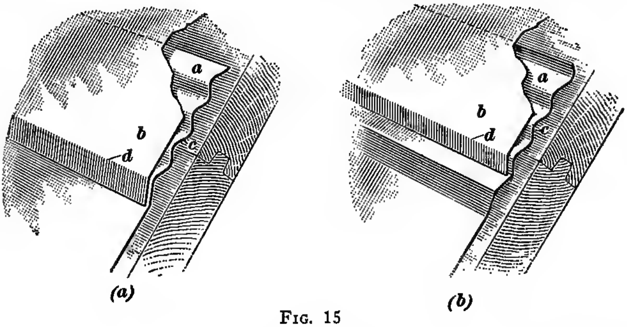


Fig. 15

In Fig. 13 at *d* and *e* are shown the methods used for forming the top and the butt joints. In Fig. 15 (*a*) and (*b*) are shown details of these joints. The top of the lower piece is shown at *a*, and the butt of the upper piece at *b*. The corrugations *c* and the bend *d* prevent the passage of water, whether due to wind or capillarity.

35. Preparation of Surfaces.—Metal shingles, slates, and tiles may be applied to a roof having a pitch of 6 inches or more to the foot. These roofings may also be applied to vertical surfaces, such as the sides of buildings, and sides of dormers.

The roof surfaces should be covered with boarding which should be matched and laid tight. It is advantageous to lay one thickness of good building paper or felt over this surface. Papers containing tar or tar products should, however, not be used as the acids in such papers will corrode the metal.

LAYING METAL SHINGLES, SLATES, AND TILES

36. Plain Surfaces.—Metal shingles are laid in courses across the roof, the successive courses extending from the eaves to the ridge. The position of the lock on the right-hand edge of the shingles makes it necessary to lay from left to right. The shingle is nailed through the edge outside the lock, as at *c* in (*a*), (*b*), and(*c*), Fig. 13, the nail heads being covered by the next shingle laid. Some types allow for nailing through the heads as well as through the side. It is advisable to use guide lines, both for the butts of the shingles and for the sides, to insure a neat-appearing roof. In some patterns of metal slates, a mark, as at *f* in (*b*), indicates the center of the slate, at which point the joint of the next course should occur.

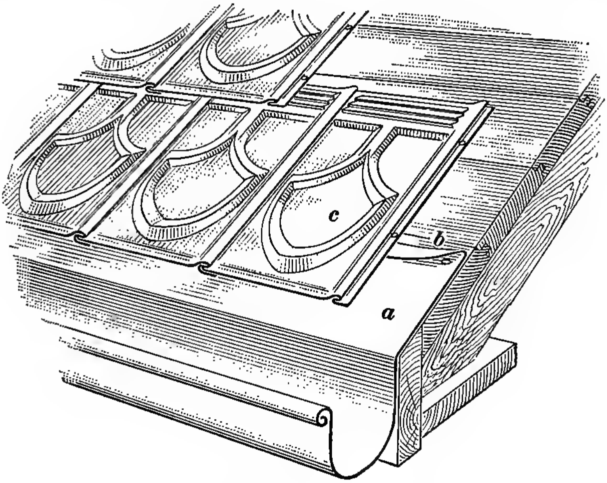


FIG. 16

37. Finish at Eaves and Gutters.—When a gutter is used at the eaves, the back of the gutter *a*, Fig. 16, extends up under the shingles a sufficient distance to insure a tight joint. The upper edge of the back is folded, as at *b*, to prevent water from being blown up under the shingles *c*. In some cases the lower edge of the shingle *a*, Fig. 17, is locked into the gutter back *b*, as at *c*. When no gutter is used, as in Fig. 18, the shingle *a* projects about 1 inch over the eaves, and is bent down and nailed to the eaves molding *b*, as at *c*.

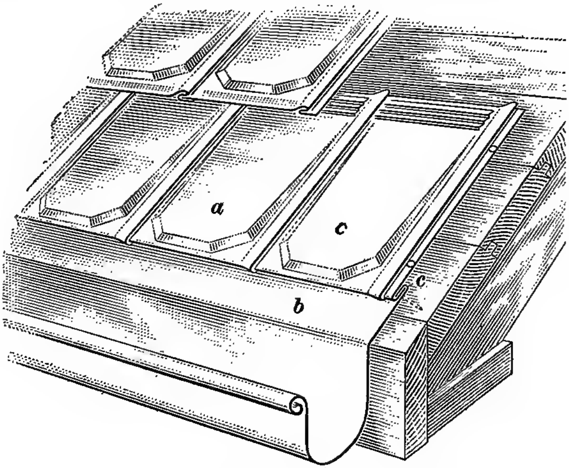


FIG. 17

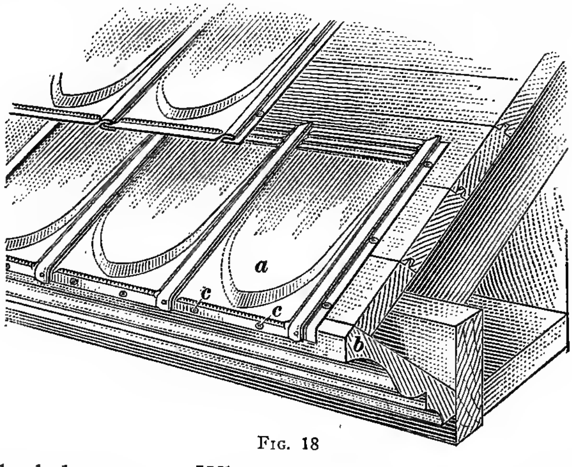


FIG. 18

38. Finish at Gables.—At the gable ends, as in Fig. 19, a metal gable finish *a* may be first applied to the edge of the roof, and the shingles *b* locked into the flange as at *c*. A somewhat similar finish used for starting Spanish tile is shown in Fig. 20, in which it will be noticed that the right-hand edge *a* of the finish *b* has the same detail as the lock *e* on the edge of the tile *d*. A simpler form of finish, shown in Fig. 21, consists of extending the edge *a* of the shingle *b* 1 inch over the gable end, and turning it down and nailing it to the boarding *c*. The gable finish in Figs. 19 and 20 may be in long lengths, or it may be in the same lengths as the metal shingles.

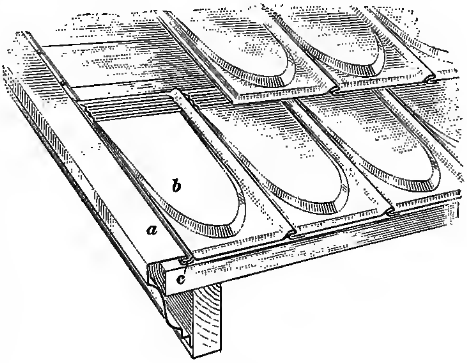


Fig. 19

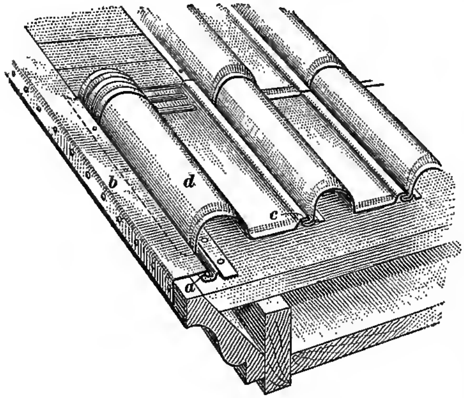


Fig. 20

39. Finish at Ridges.—At the ridge a formed metal ridge finish may be used. This piece, shown at *a* in Fig. 22, is put in place before the last course of shingles is laid, and is nailed through the flange *b*, as at *c*. The heads of the last course of shingles *d* are slipped into the fold *e*, thus protecting the nail heads from the weather, and making a weather-tight finish. This ridge finish is usually made of the same material as the roof, such as copper, galvanized iron, or tin.

Ornamental ridge rolls matching in design the type of tile represented are also used to finish metal-tile roofs. The intersections of hips and ridges are covered with finials, usually of a more ornamental design than the ridge.

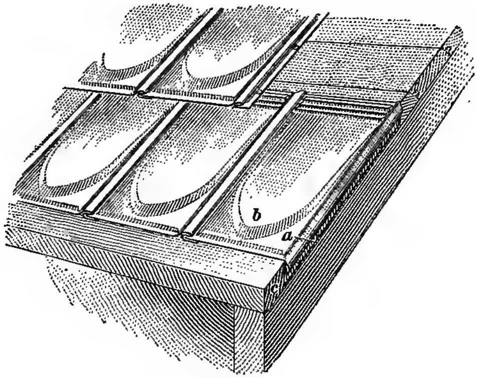


Fig. 21

40. Finish at Hips.—The same finish shown in Fig. 22 for a ridge may be used for covering hips, as at *a* in Fig. 23, being put on the roof before the last shingles *b* in the horizontal courses are laid. A more ornamental appearance may be obtained through the use of ornamental hip coverings, as shown at *a* in Fig. 24. This covering is made in one piece of metal for each course of shingles, and is laid from the top down-

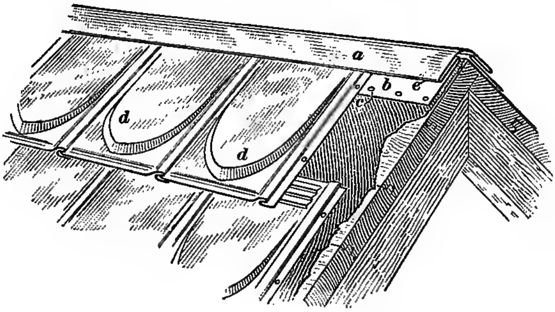


Fig. 22

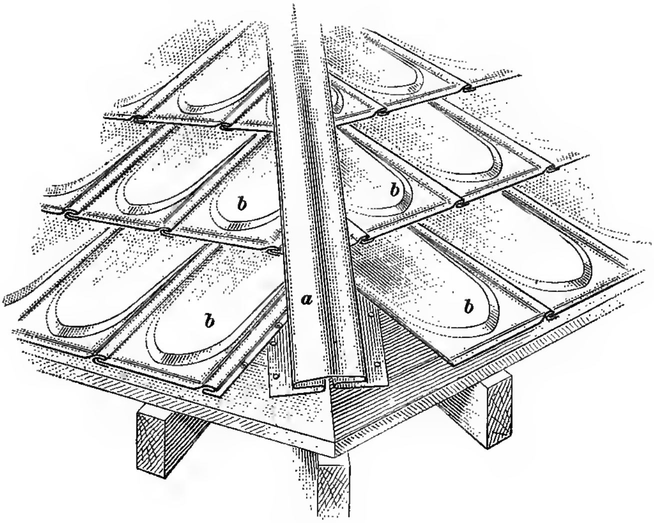


FIG. 23

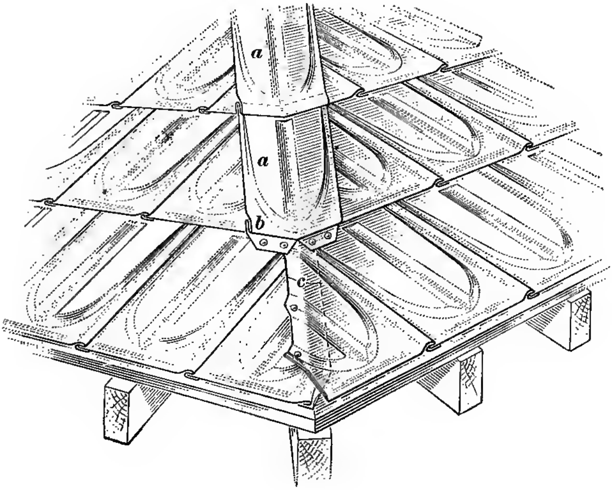


FIG. 24

wards, the lower end having projecting pieces for nailing. The lower end is bent into a fold *b* into which the top of the next lower piece is inserted, thus covering and protecting the nail heads. When this type of covering is used, the shingles are cut off on each side of the hip, leaving sufficient material to lap over the hip about 1 inch, as shown at *c*. This edge is folded over the hip, and is securely nailed. Similar hip coverings are made to match the embossing of tile roofing.

41. Finish at Valleys.—A valley lining shaped like that shown at *a* in Fig. 25 will insure a weather-tight joint.

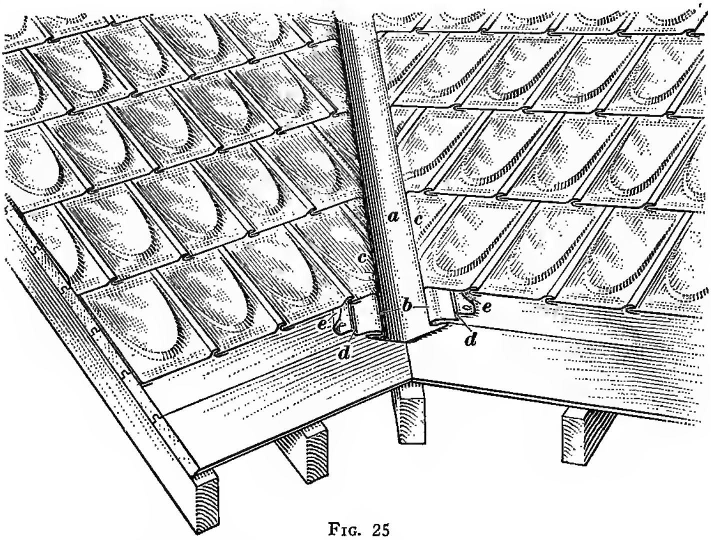


FIG. 25

The folds *b* in the valley are designed to permit the shingles *c* to lock into them, while crimps *d* and turned edges *e* prevent any water that might be driven past the locks *b* from passing on to the roof boards. The valley lining is nailed at the edges *e*. Where the shingle has much embossing, plain shingles, which are made rights and lefts, as shown in (*a*) and (*b*), Fig. 26, are used at the valleys. These shingles have the lock on one side only, as shown at *a*, the sides *b* being left plain and flat to permit trimming or fitting to the lock in the valley. Spanish tile and other forms having the embossing extending clear to the butt of the shingle are made with the roll, or embossing, terminating in the central portion of the tile, and are made rights and lefts, as shown in (*a*) and (*b*), Fig. 27. The locks on the edges *a* fit the regular tile, while the plain portions *b* can be cut to fit the valley, and to make a neat, tight joint.

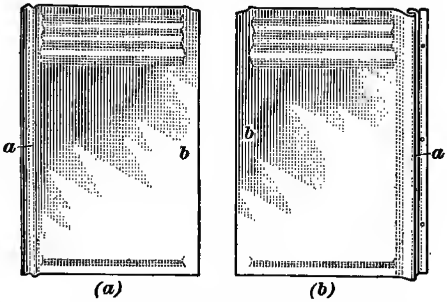


FIG. 26

Valley shingles and tiles must be nailed outside of the valley metal in order to avoid leaks.

42. Conical Roofing.—Conical tower roofs, domes, and similar surfaces may be roofed with metal plates, usually in the form of tile, graduated in size to correspond to the pitch. Special tiles must be made for each different pitch, so as to taper evenly from the eaves to the apex of the tower or dome.

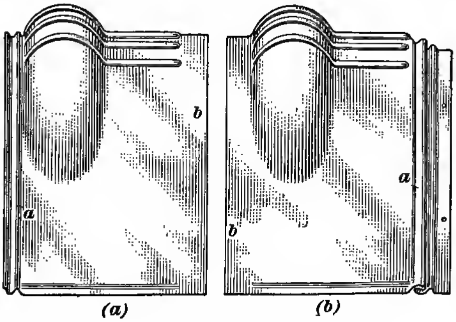


FIG. 27

In covering a roof of this character, particular care must be taken to secure plumb joints between the tiles, and to keep horizontal level lines. This is sometimes done by stretching a line from the apex to the eaves, and spacing evenly around the base of the roof. The courses are kept uniform by measuring up from the eaves course, or down from the apex.

43. Flashings.—For flashing against walls, dormers, and the like, a base flashing similar to that shown at *a* in Fig. 28 is used. The side of the shingle *b* is inserted in the fold *c* of the flashing, which is nailed to the roof sheathing, as at *d*.

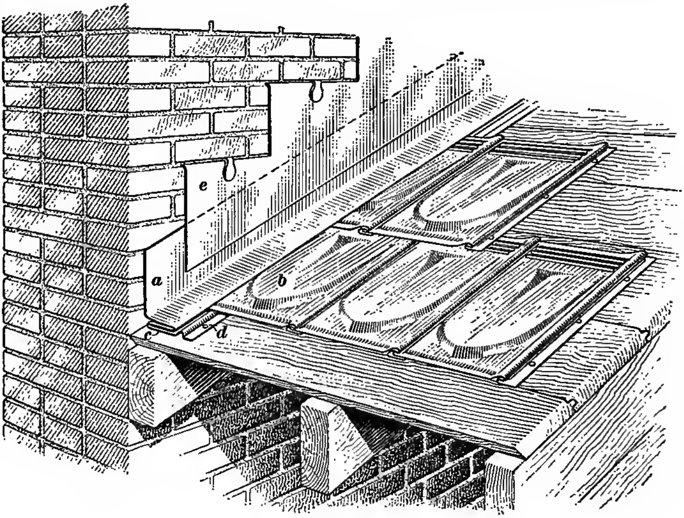


Fig. 28

The flashing is covered against the wall by the counterflashing *e*. When this base flashing is used against a frame wall, the siding or other covering laps down on the flashing to within 2 inches of the roof surface, and takes the place of cap, or counterflashing.

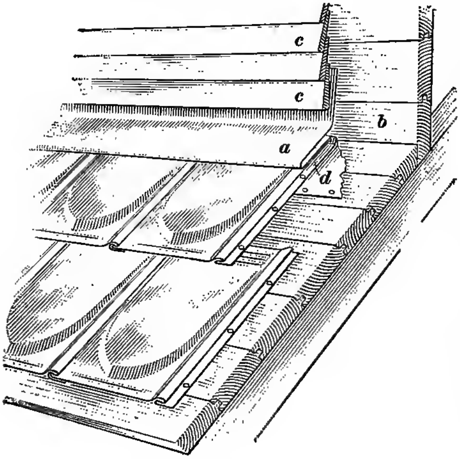


Fig. 29

44. When a sloping roof terminates against a vertical wall, porch flashings, as shown in Figs. 29 and 30, are used. When the wall is of frame construction, as in Fig. 29, the flashing *a* is placed against the sheathing *b*, and is nailed to the roof boarding. The siding *c* is brought down over the flashing, to within about 2 inches of the roof surface. The top course of shingles is inserted in the fold *d*, which holds it securely.

When the vertical surface is a brick wall or chimney, as in Fig. 30, the flashing *a* is let into the wall, as at *b*, and is secured by wall hooks *c*. The flashing is also nailed to the roof boards under the fold, as at *d*, and the tops of the shingles *e* are held in the fold. This flashing is made in lengths of 8 feet, as a rule, and is cut to the required lengths.

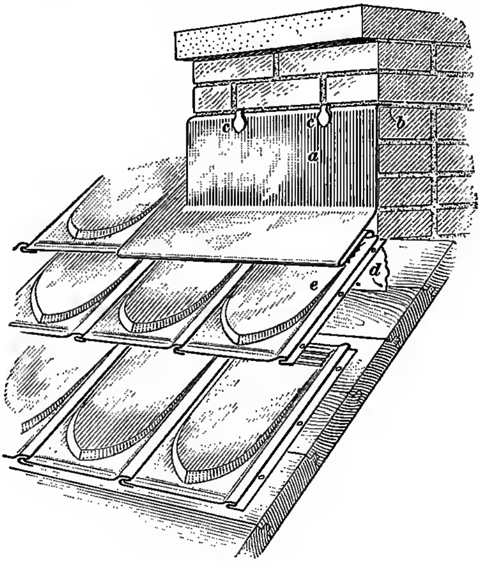
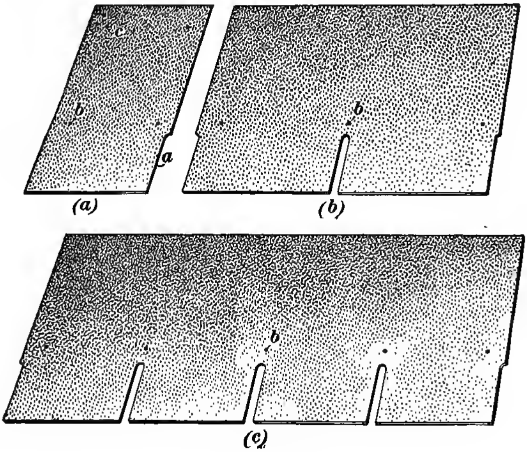


Fig. 30

ASPHALT-SHINGLE ROOFING

GENERAL CONSIDERATIONS

45. Types and Sizes of Asphalt Shingles.—Asphalt shingles are composed of heavy felt saturated with asphalt, the composition being similar to ready roofing, already described. Most of the shingles are of uniform thickness throughout, although some brands are made thicker at the butt than at the tip, to provide better wearing qualities. The shingles are made in a variety of styles and sizes, the principal styles being the *single, twin,* and *strip, shingles.* The single, or individual, shingle, as shown in (*a*), Fig. 31, is about 8 inches wide and 12¾ inches long, and in some makes have the butts cut on one side, as at *a* to give the appearance of wide joints, and to prevent water from being drawn up between the shingles. The twin shingle, shown in (*b*), consists of one piece of material 20 inches wide and 12¾ inches high, and cut at the butt to represent two shingles. The strip shingle, shown in (*c*), consists of a piece of material about 32 inches long and 10 or 12 inches high, cut to represent four shingles.



(a) (b)

(c)

FIG. 31

The weight of asphalt shingles varies with the different brands, sizes, and finishes, from about 220 to 260 pounds to the square.

46. Surface Finish.—Asphalt shingles are made with the natural finish of the saturated felt, but the more general finish consists of a coating of asphalt into which is pressed finely crushed stone, slate, or other materials. By the use of different-colored stone and slate, a variety of colors may be obtained in these surfaces, the usual colors, however, being gray, green, and red.

47. Pitch.—Asphalt shingles are suitable for roofs where the pitch is 6 inches or more to the foot, although for small roofs, such as porches, they may be laid at a lower pitch. They are used for roofs of residences, garages, barns, and other similar buildings, wherever wooden shingles might be used.

LAYING ASPHALT SHINGLES

48. Plain Surfaces.—A tight surface, formed of boards laid with close joints or of matched boards, is required for asphalt shingles. In general, the shingles are laid with a 4-inch gauge, or exposure to the weather, in the same manner as wooden shingles. Under the first course, at the eaves, it is advisable to lay a single course of wood shingles, to support the overhanging edge of the asphalt shingles. The single shingles are laid with a ½- or ¾-inch joint between them, unless the butts are cut as at *a* in (*a*), Fig. 31. Barbed nails 1 inch to 1⅛ inches long with large heads should be used. The shingle should be nailed about 5 inches up from the butt, as at *b*, although sometimes the shingle is nailed near the top, as at *c* in (*a*). This latter method provides a better covering for the nail heads, but does not hold the shingles so securely as when nailed as at *b*. Three nails are required for the twin shingle, as shown at *b* in (*b*). The strip shingle shown in (*c*) is secured by five nails, as shown at *b*.

49. Finish at Valleys.—Metal valleys, as already described for wooden shingles, may be used with asphalt shingles; but a more logical method is to use ready roofing of the same finish and weight as the shingles. Close valleys may be made by the use of flashings with each course, or open valleys, with strips extending from bottom to top of the valley. In the latter case it is customary to use two strips of the ready roofing, the under strip being about 12 inches wide, and laid with the finished surface down. The top strip is laid with the finished surface up, thus bringing the two backs of the strips together. The top strip is usually about 18 inches wide, and on it are struck two chalk lines or guides in cutting the shingles at the valley. These lines should be about 3 inches from the bend of the valley at the bottom, and about 1½ inches at the top.

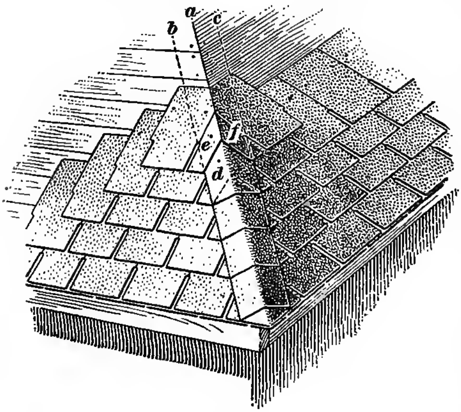


FIG. 32

50. Finish at Hips.—A Boston hip may be laid as shown in Fig. 32. The method is similar to laying a Boston hip with wooden shingles, except that the asphalt shingle is folded over the hip-line *a* and is fitted to the lines *b* and *c* on the roof slopes. The sides of the hip shingles, as at *d*, fit against the shingles *e* and *f*.

51. Finish at Ridges.—The ridge of asphalt-shingle roofs may be finished by folding the top shingles over the ridge, and finishing with a ridge course of shingles extending down the same distance on both sides. Ornamental wood or metal ridge rolls may also be used, the application being the same as described for wooden-shingle roofing.

52. Flashings for Asphalt-Shingle Roofing. Metal flashings may be used in the same manner as with wooden shingles, in flashing asphalt-shingle roofs. Ready roofing, or asphalt shingles, may also be used with equally satisfactory results. Counterflashing on brick walls should be metal, in order that it may fit well into the raked-out joint, or raggle, of the wall. The application of these flashings is the same as already described for other forms of roofing.

53. Laying Asphalt Shingles Over Old Shingle Roofs.—Asphalt shingles may be laid over old wooden-shingle roofs by the method shown in Fig. 33. The under course of asphalt shingles *a* at the eaves, is first laid, the length of the shingle being equal to the gauge of the wooden shingles. The next course *b* is cut to a length equal to the gauge of the first two courses of wooden shingles and laps over the course *a*. The third course *c* has a length equal to three courses of wooden shingles, and laps or covers the courses *a* and *b*. The butts of this course form the first exposed surface, as at *d*. The next course *e* is laid to the butts of the fifth course of wooden shingles, as at *f*, and the succeeding courses of asphalt shingles are laid to the butts of the next higher course of wooden shingles.

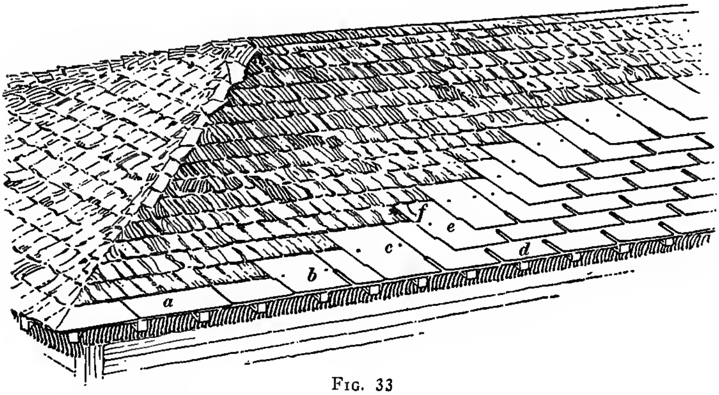


Fig. 33

Longer nails are required for fastening asphalt shingles to the roof over old wooden shingles, as the nails must penetrate to a solid nailing in the shingle lath or roof boarding. Large-headed barbed nails, coated or galvanized, from 1¾ to 2 inches long, are used in this method.

54. When the wooden-shingle roof is in very poor condition, having areas of the wooden shingles entirely missing, this method cannot be used to advantage, as the finished roof would have an uneven appearance. In such cases the remaining shingles must be removed, and the surface made solid by new sheathing, or by filling up the spaces between the shingle lath or roof boards.

SLATE ROOFING

55. Slate used for roofing purposes, commonly known as *roofing slate,* is obtained from a sedimentary rock, which splits very readily into thin slabs. These slabs are cut up into rectangular sheets and form a very valuable roofing material.

56. Qualities of Slate.—Good slate should possess both toughness and hardness, and a very fine, but easily distinguishable, grain. The slate should be tough enough to be easily punched for nailing, and should permit of being cut without splintering at the edges. The slate should not absorb much moisture, as the action of frost on the moisture will cause the edges to crumble and will also tend to enlarge the nail holes, thus causing the slate to loosen from the roof.

The grain should run lengthwise of the slate. The color of slate varies considerably, and is in no way indicative of the quality of the material. Blue, blue-black, purple, gray, green, red, and mottled are the most common colors. Color is not always permanent, some of the slates fading perceptibly after long exposure to the weather.

Slate often contains veins or ribbons of a different color. These veins may not impair the strength of the slate, but are objectionable in appearance.

A good slate should present a bright, silk-like luster, and should give out a clear, metallic ring when struck with the knuckles, showing that it is hard. If it is soft, it will have a dull, lead-like surface, and will give out a muffled sound. When cut, the edges should show a fibrous texture, free from splinters, and the material should not show signs of being either brittle or crumbly.

No better test of the wearing or weathering qualities can be applied than the simple and effective one of examining roofs where the slate has been in service for several years.

57. Terms Used in Slating.—The terms applied to the different parts of roofing slate are: the *gauge,* or *weather,* which is that part of the slate which is exposed when laid, as shown at *a,* Fig. 34; the *lap,* which is the distance that each slate overlaps the second one below it, as at *b*; the *head,* or upper end, of the slate, as at *c*; and the *tail,* or lower end, of each slate, sometimes called the *weather edge,* or *butt,* as at *d.* The *bed* is the under surface of each slate when laid, and the *back* is the upper surface when laid. The gauge for any slate may be found by first subtracting the lap from the length, and dividing by 2. The maximum gauge that should be allowed for any slate is determined by allowing for a standard 3-inch lap, and dividing the remainder by 2. For roofs of lower pitch than 6 inches to the foot, the lap should be 4 inches. In some cheap and unimportant work the lap is made less than 3 inches, but this practice is not to be recommended for permanent work of the highest grade.

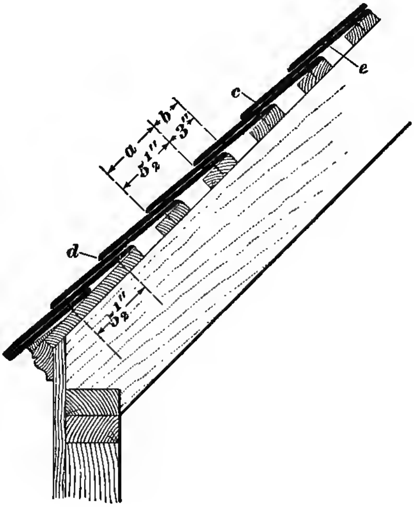


Fig. 34

58. Sizes of Slates.—Slates are made in a number of sizes, as shown in Table I. This table gives the commercial sizes of slates, the gauge with a 3-inch lap, and the number of square feet of roof surface covered by one hundred slates, the number of slates required to cover a square, and the weight per square for the various sizes of slates when slates $\frac{3}{16}$ inch and $\frac{1}{4}$ inch are used.

59. Number of Slates Required.—Slating is calculated by the square of 100 square feet. To ascertain the number of slates of a given size required to cover a square, subtract the lap—usually 3 inches—from the length of the slate to be used, and divide by two, which will give the gauge. Multiply the gauge by the width, which will give the area covered by each slate. Divide 14,400, the number of square inches in a square of roofing, by the number of square inches covered by each slate, and the result will be the number of slates required for a square of roof. Thus, a slate 16 by

TABLE I

SLATE STATISTICS

Size of Slate in Inches	Gauge With 3-Inch Lap	Square Feet Covered by 100 Slates	Number of Slates to Square	Weight per Square	
				$\frac{3}{16}$ Inch Thick	$\frac{1}{4}$ Inch Thick
24×14	10½	101	98	633	844
24×12	10½	87	115	633	844
22×12	9½	79	126	634	847
22×11	9½	72	137	635	847
20×12	8½	71	142	650	867
20×10	8½	59	170	650	867
18×12	7½	62	160	661	881
18×10	7½	52	192	661	881
18×9	7½	47	214	661	881
16×12	6½	54	185	678	904
16×10	6½	45	222	678	904
16×9	6½	41	247	678	904
16×8	6½	36	277	678	904
14×10	5½	38	261	698	931
14×8	5½	31	327	698	931
14×7	5½	27	374	698	931
12×8	4½	25	400	733	977
12×7	4½	22	457	733	977
12×6	4½	18	533	733	977

12 inches with a 3-inch lap will have a gauge of $(16-3)\div 2 = 6\frac{1}{2}$ inches, and will cover $6\frac{1}{2}\times 12=78$ square inches. It will require $14{,}400\div 78=185$ slates, to cover one square. 100 slates will cover 7,800 square inches, or 54 square feet.

An allowance of about 6 per cent. for cutting and waste should be made for plain roofs, and about 12 per cent., or even more, if the roof is cut up with hips and valleys.

60. Punching Slate.—The holes through which nails are driven for fastening slates to roof boarding may be made by drilling or by punching. The punching may be done by hand or by machine. The drilling is the best method, and must be used when thick slates are used, as thick slates cannot be punched. When a slate is drilled, the back of the slate is countersunk, which provides room for the heads of the nails, as at *a* in Fig. 35 (*a*). The holes made in this way are quite clean cut, and a space is formed sufficient to take the nail head. In forming nail holes by hand punching, the slate about the back of the hole is apt to flake off more than with the other methods, and the strength of the slate at the holes is diminished.

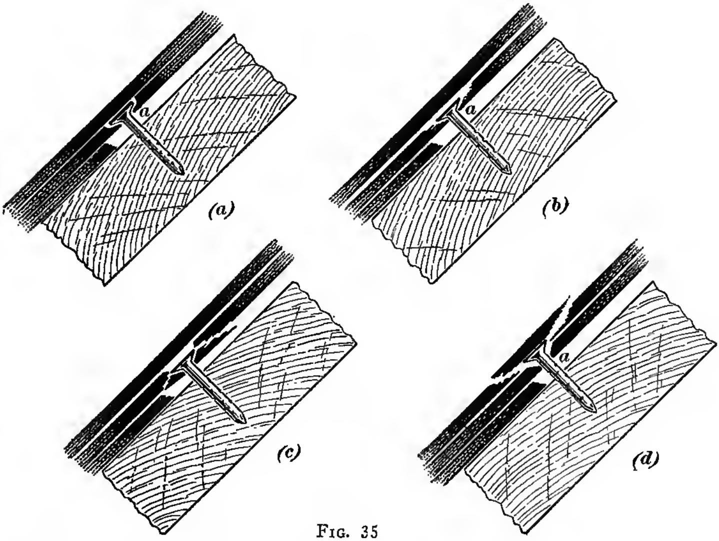


FIG. 35

A hand-punched hole is shown at *a* in (*b*). It will be seen that the upper part of the slate has been driven off by the blow necessary to make the hole.

61. Driving Nails.—A great deal of skill is required in nailing a slate properly. If the nail is driven too far, as in (*c*), Fig. 35, the slate may be broken and the nail will not hold the slate. If the nail is not driven far enough, as at *a* in (*d*), the slate that rests on the nail head may break as shown. This will happen especially if there is any pressure from above.

62. Nails for Slating.—The nails used for slating have large, flat heads, so that they may get a good hold on the surface of the slate. The proper length of a nail is twice the thickness of the slate, plus a little less than the thickness of the boarding or lathing; this length will give the full amount of hold that can be secured. The nails generally used are threepenny, which are 1⅛ inches long, and fourpenny, which are 1⅜ inches long. Barbed nails hold better than plain nails, and copper, non-corroding composition, or galvanized-iron nails are preferable to plain iron nails, as the plain iron nails are subject to destruction by rust, allowing the slates to drop out. The amount of nails used will vary for different sizes of slates, from about 1 pound to the square for 24″×14″ slates, to about 5 pounds for 12″×6″ slates.

METHODS OF LAYING SLATE ROOFING

63. Preparation of Roof Surfaces.—A solid board roof, made of matched boarding planed to a uniform thickness, forms the best surface upon which to lay slates. A layer of felt is sometimes laid over the roof boards as shown in Fig. 36, and makes an excellent surface upon which to lay the slates. The felt is often omitted, however, as a matter of economy.

Slates are also sometimes supported on battens, or laths, similar to those used in shingle roofs. These laths are from 2 to 3 inches wide, and ⅞ to 1⅛ inches thick, and are spaced a distance apart equal to the gauge, or exposure, of the slate. The laths are usually placed so that the top edges will serve as guides in laying the slates, as at *a*, Fig. 37. A disadvantage in using battens is that dust and snow are blown through the crevices in the slate, and enter the attic between the battens. This cannot happen when the roof is tightly boarded and covered with paper.

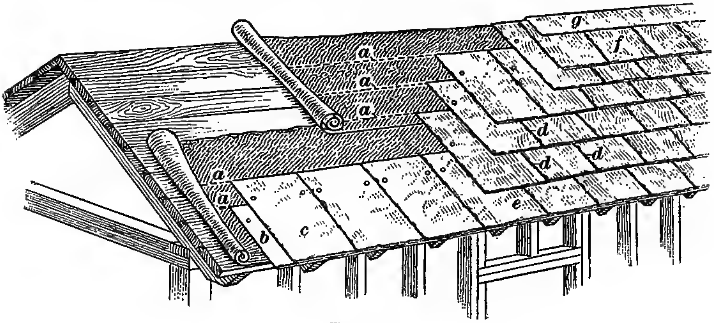


FIG. 36

In fireproof roofs, where the slate roofing is to be supported on the steel, angle irons are attached to the rafters, and spaced so that each slate can be tied to the angles by means of copper wire. In some cases terra-cotta blocks are set in between the angles, and the slates are nailed to these blocks.

64. Laying Slate Roofing.—In Figs. 36 and 37 is illustrated the method of laying slate roofing on plain surfaces. Fig. 36 shows the slate applied on a sheathed and papered surface. Fig. 37 shows the slate applied on battens.

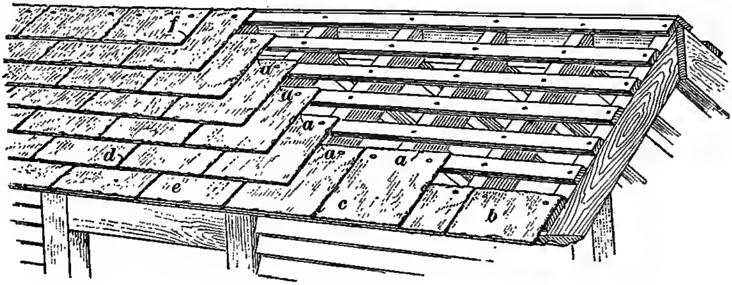


FIG. 37

In Fig. 36, gauge lines *a* are struck on the paper, and the heads of the slate are laid to these lines. The first course of slate consists of two layers. The under layer *b* has a length equal to the gauge plus the lap, and is laid with the back down. The butts should project over the eaves from 1½ to 2 inches. The upper layer *c* is a slate of the full length, and is placed so as to cover the joints in the under layer. The succeeding courses are laid with the joints broken as at *d*, and with the proper gauge, as at *e*. The top course *f* is known as a finisher, and receives the ridge piece *g*.

In Fig. 37 the slates are laid to the tops of the battens, or shingle laths, as at *a*. In other respects the method followed is similar to that shown in Fig. 36, the same reference letters referring to the corresponding parts.

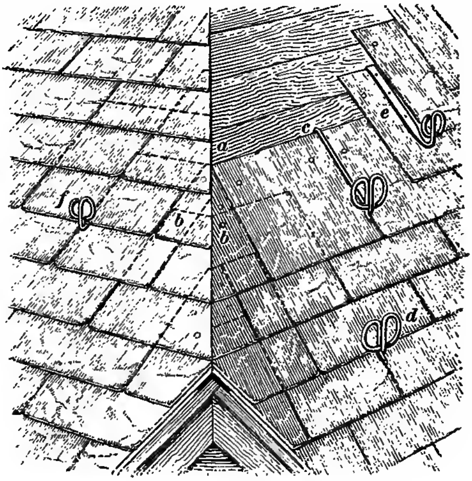


Fig. 38

65. Finish at Hips.—Hips in slate roofs may be finished in the same manner as described for shingle roofs. Tight, or close, hips, illustrated in Fig. 38, are chiefly applicable to steep slopes, such as towers and mansard roofs. The regular slates are laid with the upper corners touching the hip line, as at *a*, care being taken, however, that no small pieces are required to fill out the courses. The course is then filled out to the hip line with pieces, as at *b*. Slates cut as at *b* should rest on a bed of mastic, or elastic, cement, both to insure water-tightness of the joint, and to assist in holding the slate in position.

66. A Boston hip on a slate roof is formed in almost the same way as on a shingle roof. Fig. 39 illustrates the construction of such a hip. The lines *a* and *b* are struck on either side of the hip line to serve as guides. One point of the butt of the slate *c* is placed at the intersection of the line *d e* and the line *b*. The distance *d e* must be sufficient to look well on the roof, and the slate *c* must also be wide enough to receive two nails. A slate *f* is then cut and set in place as shown, which brings the slates *c* and *f* in the same plane. The nailing should be carefully done so as to leave no nail heads exposed. It is also advisable to bed the hip slate *f* in elastic cement, which will serve to hold it firmly in place.

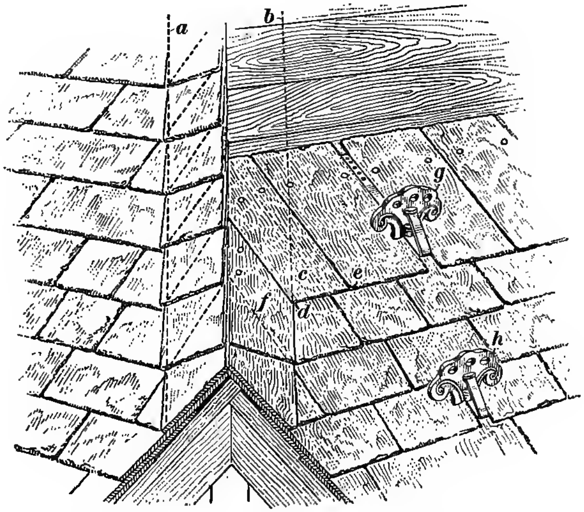


Fig. 39

Sometimes metal flashings are placed under the hip slates, both in tight and Boston hips, to insure a perfectly waterproof joint. If care is used in laying the hip, however, this will be unnecessary.

Hip rolls of metal or terra cotta may be applied to hips of slate roofs, but in general they are not to be recommended, as they will not harmonize well with the slate roof.

67. Finish at Valleys.—Valleys in slate roofs may be close or open, as described for wooden shingles. When open, as in Fig. 40, the distance from the edges of the slates to the center line of the valley at the top of the valley should be not less than 2 inches, increasing in width ½ inch for every 8 feet toward the bottom of the valley. The valley metal *a* should run under the slate at least one-half the width of the slate as at *b*. The edges of the valley should be turned as at *c*, and secured to the roof by cleats *d*. All nailing of the slates, as at *e*, should be outside the metal, to avoid causing leaks.

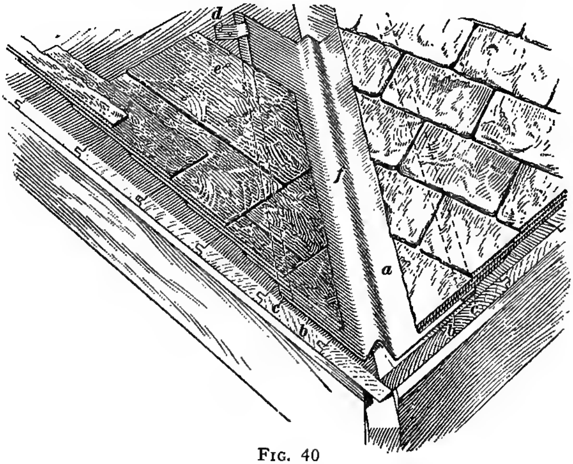


FIG. 40

When the roof slopes forming the valleys are at different angles, or have different areas, so that different volumes of water are discharged into the valley from the two sides, crimped, or standing-seam, valleys, are advisable. The purpose of the crimp, or seam, in the center of the valley is to break the force of the flow of water, so that water flowing from one slope will not force its way up under the slate on the opposite side. A typical **V**-crimp valley is shown at *f*, Fig. 40.

68. Finish at Ridges.—The ridge of a slate roof may be finished as shown in Fig. 41. The wooden saddle strips *a* are nailed to the roof boards, to which is nailed a wooden roll *b*. The slate roof is carried up to the wooden strips, and the top course is nailed close to the head, the nail heads being covered with elastic cement. A metal ridge roll *c* is then slipped over the wooden saddle and roll, and is nailed in place, as at *d*. The nail heads are afterwards soldered over or covered with elastic cement. This ridge roll is nailed to the roof boards through the slate, and to avoid breaking the slates, the nailing should be done between the slates of the top course. The flange *e* of the metal ridge should be at least 3 inches wide to cover the slate nails *f* properly, and to prevent water from entering over the tops of the slates. Copper should be used for metal ridges on slate roofs, as other metals require painting, and this is not easily done after the roof is completed.

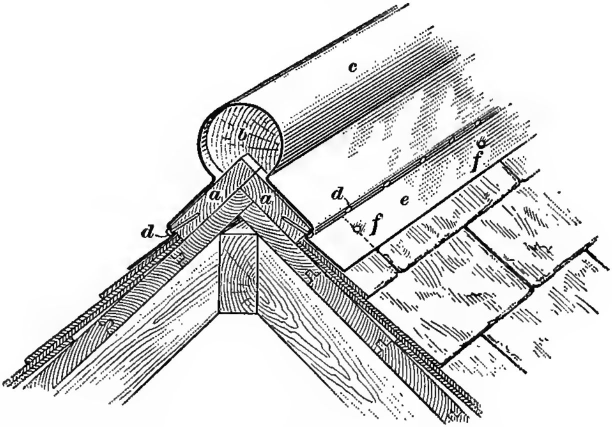


Fig. 41

69. Where the slates are laid over sheathing paper on tight boarding, as in Fig. 42, the sheathing paper is lapped over the ridge, as at *a*, and the slate on one side of the roof is finished close up to the ridge, as at *b*. The slate on the opposite side of the roof is then finished so as to extend over the ridge, sometimes as much as 1½ inches, as at *c*. It is recommended that with this type of ridge the top courses of slate on each side of the ridge be bedded in elastic cement, and all exposed nail heads, as at *d*, be covered with elastic cement. The overlapping slate *c*, or comb, should be on the side of the building from which the wind, snow, and rain come.

Ornamental sheet-metal ridges, as at *a*, in (*a*), (*b*), (*c*), and (*d*), in Fig. 43, as well as terra-cotta ridges, are sometimes used on slate roofs, but the effect is not so pleasing as when a simpler finish is applied.

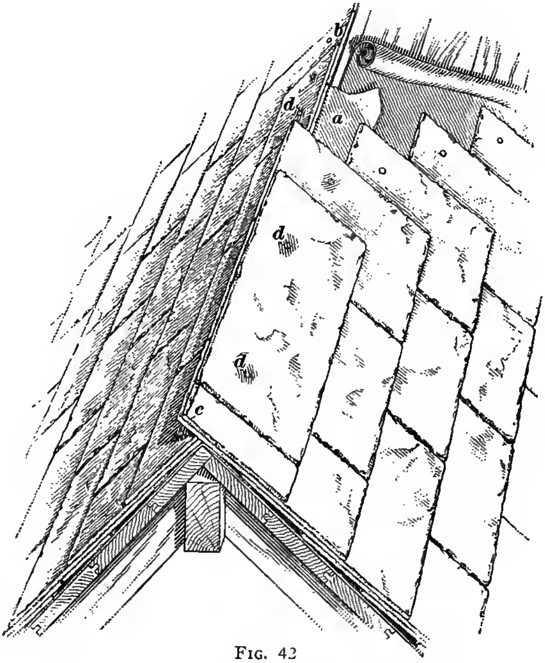


FIG. 42

70. Slating Conical Roofs.—In slating conical towers, the same method is followed as explained for wooden shingles, and shown in Fig. 5. Commencing at the lower courses with slate from 6 to 10 inches wide, the width is gradually decreased until a width of 2 inches is reached. This is about the narrowest size that will safely cover the nail holes and joints, and keep the weather from penetrating the roof. Even with this width of slate, the upper courses should be well bedded in elastic cement, in order to secure a permanently tight roof.

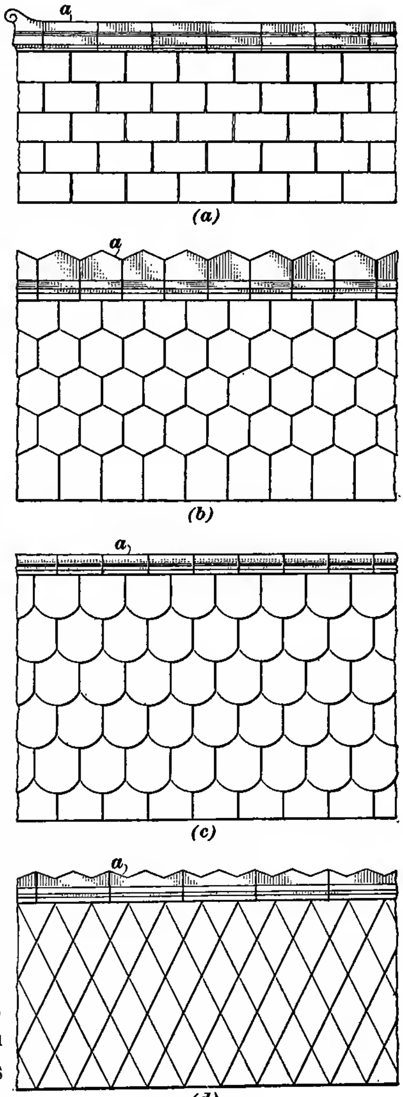


Fig. 43

ORNAMENTAL SLATE ROOFING

71. Cut Slate.—Slate roofs may be ornamented by the use of bands or patterns of slates having the tails, or butts, cut on the corners so as to give, when laid, an appearance varying from the straight lines formed with plain square slates. These slates are termed *cut slates*, and some of the commoner styles are shown in Fig. 43. Plain slates are shown in (*a*), hexagon slates in (*b*), round butts in (*c*), and diamond points in (*d*). The first course is usually laid with square butts, to avoid a sawtooth or irregular effect at the eaves, which would be objectionable.

72. Old European Graduated Method.—Another method of securing pleasing effects, by using slates of varying lengths, widths, and thicknesses, is shown in Fig. 44. In this method, sometimes called the old European graduated method, the thicker slates of the larger sizes are used in the lower courses of the roof. The thickness and gauge decreases gradually toward the ridge, while the slates are of varied widths in every course. These widths are known as random widths, although in general the wider slates are used for the lower courses. The slates used in this method are from ¼ to 1 inch in thickness. The use of slates decreasing in thickness from eaves to ridge gives textural effect and perspective, the use of slate varying in size relieves the monotony of equal rectangles,

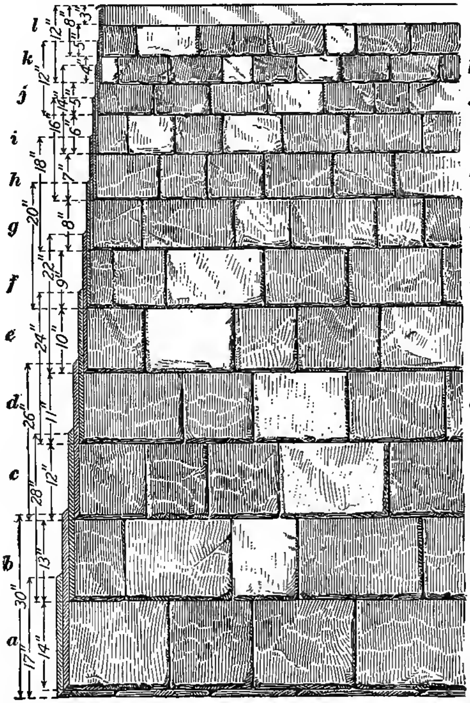


Fig. 44

while the varying widths break up the vertical and diagonal effects.

In Fig. 44 the under course at the eaves is 17 inches long, to provide for a 14-inch gauge for the first course *a*, which is 30-inch slate 1 inch thick. Courses *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *j*, *k*, and *l*, are slates 28, 26, 24, 22, 20, 18, 16, 14, 12, 12, and 8 inches long, respectively, varying from 1 inch to ¼ inch thick. With 3-inch lap the gauge varies from 14 to 3 inches. Course *l* is 8 inches long and, when a 3-inch ridge is applied over it, will show 5 inches. It may be noted that the length of any slate is equal to its gauge plus the gauge of the slate next above, plus the 3-inch lap. Thus the slate with the 12-inch gauge plus the 11-inch gauge of the next slate above, plus the 3-inch lap, requires a 26-inch slate. In a graduated roof, the lap is not always equal to one-half the length of the slate

TABLE II

THICKNESSES AND LENGTHS OF SLATES REQUIRED FOR A TYPICAL OLD EUROPEAN GRADUATED SLATE ROOF

Courses	Thickness Inches	Length Inches	Gauge Inches
Under course at eaves	1	17	0
a	1	30	14
b	1	28	13
c	¾	26	12
d	¾	24	11
e	½	22	10
f	½	20	9
g	½	18	8
h	⅜	16	7
i	⅜	14	6
j	⅜	12	5
k	¼	12	4
l	¼	8	5

after deducting the 3-inch lap, as the lap is varied to suit the gauge desired.

The effect of the roof may be further varied by using slates of different colors, blue, blue-black, purple, gray, green, red, or mottled being obtainable in any of the thicknesses or sizes.

A detailed list of the sizes of slates required for the roof shown in Fig. 44 is given in Table II.

73. Curved Valleys.—When the main roofs of a building are laid graduated, the valleys are sometimes laid round.

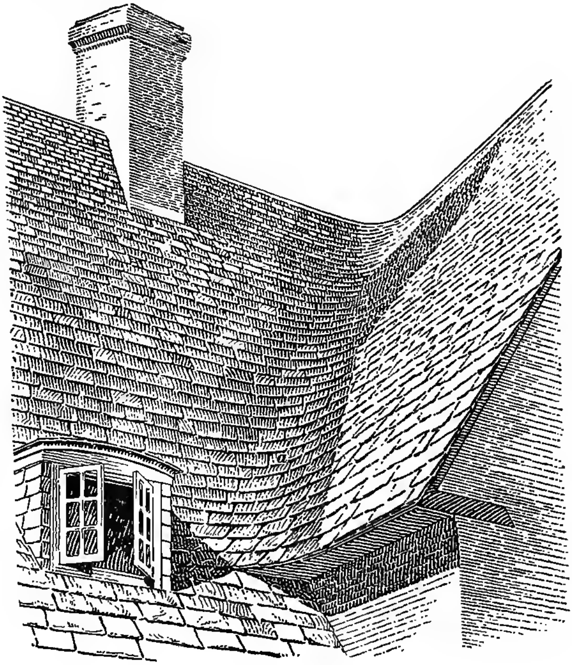


FIG. 45

The roof boards at the valleys are run lengthwise of the valley, and are brought out to give a gradual curve to the slate surface, as shown at *a* in Fig. 45. The same thicknesses and lengths of slates are used in the corresponding courses in the main roofs, but narrower slates are used in order to bring the slate nearer to the roof boarding, and to make a tighter roof. Valleys laid in this manner require careful flashing over every slate in the curved portion, and the heads of the slates are laid in elastic cement to reduce the possibility of snow and rain driving through the crevices. The valley boarding should also be covered with two-ply roofing felt, over which the sheathing paper of the main roof slopes may be lapped, to assist in making a tight roof.

74. Curved Eaves.—When the rafters are curved near the eaves, there will be open spaces under the centers of the slates, and care must be observed that no weight comes on that part of the roof. The slates should all be nailed near the heads, and the nails cemented, to obtain a tight roof. The spaces under the centers of the slates are sometimes built up with wooden lath, in order to form a support for the slate.

FLASHINGS FOR SLATE ROOFS

75. Where a slate roof finishes against a parapet or other vertical wall, as in Fig. 46, both flashings and counterflashings should be provided. Lead, copper, or galvanized iron may be used for this purpose. The flashings are cut in short lengths, 1 or 2 inches longer than the unexposed portions of the slate, as at *a*, and are nailed to the wood boarding through the top edge. The flashing should have a lap on the roof equal to the width of a slate, and should turn up against the wall at least 4 inches. This flashing should not be nailed to the wall, for, if the roof were to settle, the flashing would lift the slates or break them. The counterflashing *b*, which covers the upright portion of the flashing, is stepped into the joints of the brickwork as shown, and the top secured by wall hooks *c*, the raked-out joints being filled and pointed with elastic cement.

76. Snow Guards.—Snow guards, such as have been already shown in Figs. 11 and 12, may be used in connection with slate roofing, as shown in Fig. 38, at *c*, *d*, *e*, and *f*. Another form of guard, shown in Fig. 47, is made of a steel shank *a* to which a malleable-iron guard *b* is riveted. Guards of this type are often made quite ornamental. The application of this type of guard to a slate roof is shown in Fig. 39 at *g* and *h*.

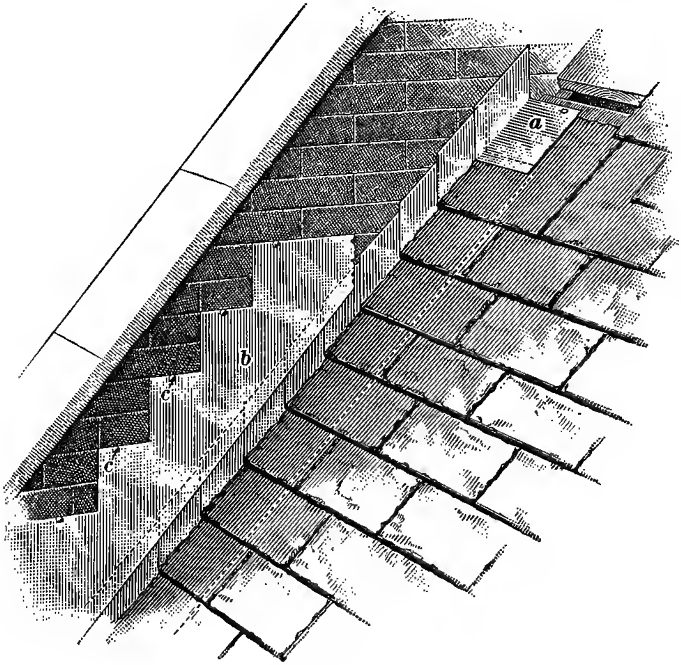


Fig. 46

A form of snow guard, shown in Fig. 48, is designed for use with slate or tile roofing already in place. The rod *a* is forced up between the layers of roofing to the head of the slate or tile. The end *a* then turns, due to the action of the spring at *b*, and hooks over the head of the slate or tiles, thereby being held securely in place.

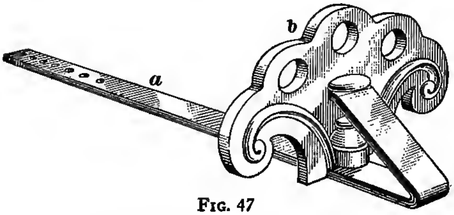


Fig. 47

77. Number of Guards Required.—The number of snow guards to be used to the square of roof surface where the guards are spaced over the entire roof surface depends on the pitch, the size of the slates or tiles, and the amount of snowfall in any locality. Steep roofs and towers require more guards than roofs of less pitch, and it is customary also to space the guards closer near the eaves.

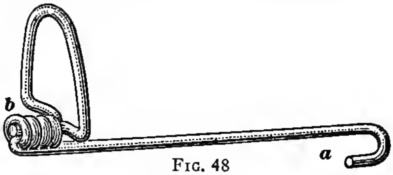


Fig. 48

TABLE III

NUMBER OF SNOW GUARDS REQUIRED PER SQUARE FOR ROOFS OF DIFFERENT PITCHES

Pitch of Roof	Number Required	
	New Roof	Old Roof
One-quarter	50	75
One-third	75	125
One-half	150	150
Gothic or towers.....	1 in every joint	1 in every joint

For ordinary weather conditions the number of guards required is shown in Table III.

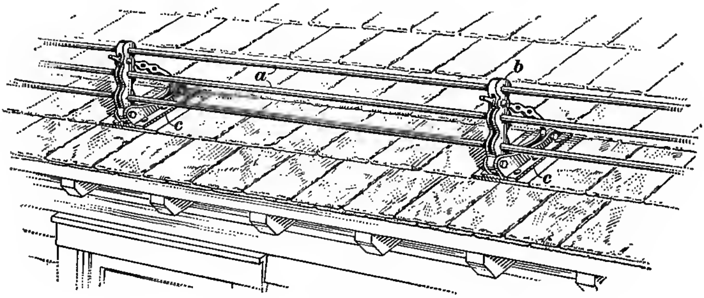


Fig. 49

78. Guard Rails.—Guard rails, shown in Fig. 49, are sometimes used on large roofs, either alone or in connection with snow guards. These rails are usually placed near the eaves and consist of 1-inch pipes *a*, supported by adjustable brackets *b*, which are attached to plates *c*. Different styles of plates are used to conform to the type of roofing used, and are fastened to the roof boarding or framing. Guard rails add to the safety of the workmen on the roof, as well as prevent the snow from sliding off.

ASBESTOS-SHINGLE ROOFING

79. Manufacture.—The principal ingredients of which asbestos shingles are made, are asbestos fiber and Portland cement. Small quantities of other materials are sometimes added to make a more waterproof or stronger material. These ingredients are pressed into thin flat shingles of uniform thickness. The principal ingredients are fire resisting, and when used in proper proportions are non-absorbent. This gives to the shingles valuable qualities.

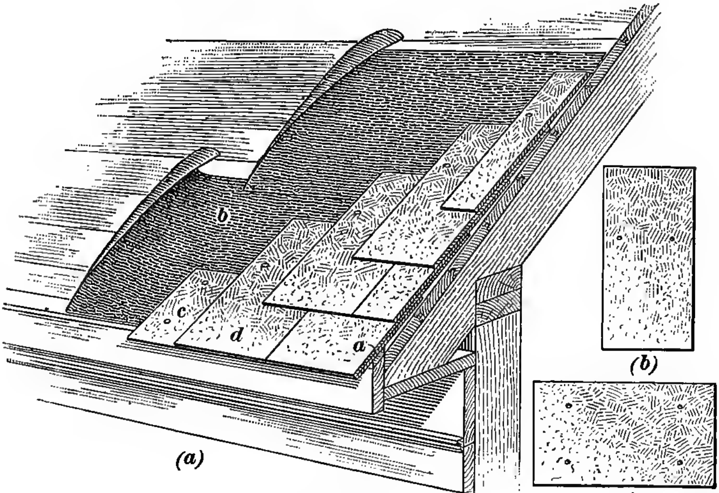
Asbestos shingles are usually left in the natural color of the composition of which they are made, which is a light gray. They are also given a variety of colors by the addition of coloring matter. Being made of a plastic material, asbestos shingles can be made in various shapes without the waste of material.

80. Shapes of Asbestos Shingles.—The usual thickness of asbestos shingles is about $\frac{1}{8}$ inch, although some are made about $\frac{1}{4}$ inch thick. The edges of the shingles are usually square, but the thicker shingles are usually left with a rough edge to produce textural effects when laid on the roof.

The weight of asbestos shingles as laid on the roof varies from 300 to about 650 pounds to the square, depending on the thickness and method of laying.

The shapes in which asbestos shingles are made allow of their being used on roofs with pitches of 4 inches or more to the foot.

81. Preparation of Roof Surfaces.—Asbestos shingles can be laid on laths, or battens, but are best laid on tight boarding covered with roofing felt. Practically the same conditions must be met in asbestos roofing as in slate roofing. The eaves molding should be set about ½ inch above the surface of the roof boards, or else a wooden strip *a* in Fig. 50 (*a*), should be nailed at the eaves. The paper or felt *b* is then laid.



(*a*) (*b*) (*c*)

Fig. 50

LAYING ASBESTOS SHINGLES

82. There are three methods of laying asbestos roofing, the American, diagonal, and hexagonal methods. These methods produce roofs of different designs, and require shingles of different shapes to carry out the designs.

83. American Method.—In the American method, illustrated in Fig. 50 (*a*), the shingles are rectangular, about 8 inches in width and 16 inches in length. A typical shingle is shown in (*b*). A shingle used as a starter is shown in (*c*), and is 8 or 9 inches wide and 16 or 18 inches long. The method of laying these shingles is similar to that used in laying slate roofing. The starting shingles are laid along the eaves, as at *c* in (*a*), and project about 1½ or 2 inches. The regular shingles *d* are laid on top of the starting shingles. The lap used is from 2½ to 4 inches, and the gauge, or exposure, is from 6 inches to 6¾ inches. Each shingle is nailed with two galvanized-iron or composition nails.

84. Diagonal Method.—The diagonal method, sometimes called the *French* method, is illustraed in Fig. 51. This method requires three different shapes of shingles. For the under-course shingles at the eaves, starters *a* in view (*a*) are required. Over this course is laid a second course of starters that are pointed as at *b*. The shingles used for the principal part of the roof are shown at *c*. These are usually 12 inches by 12 inches or 16 inches by 16 inches in size, and are nailed to the roof with galvanized or composition nails as at *d*. The shingles are further secured by the use of storm nails, made of copper, and shown in (*b*). These nails are placed between the shingles, as at *e* with the point projecting. This point projects through the point of the shingle which overlaps and is bent down as at *f*. This holds the shingle from loosening in a strong wind.

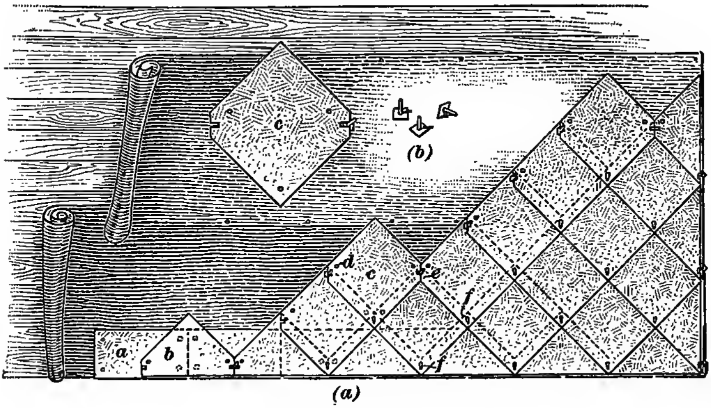


Fig. 51

85. Hexagonal Method.—The hexagonal method, also called the *honeycomb method*, is shown in Fig. 52. It is practically the same as the diagonal method. The butts of the shingles are, however, cut as shown, to give a hexagonal appearance to the roof.

86. Finish at Hips.—In the American method, the hips may be laid in the same manner as with wooden shingles or slates. With the diagonal or hexagonal methods, however, the usual practice is to use a half-round hip roll, as shown at *a* in Fig. 53 (*a*). A wooden strip *b*, 1 inch by 2 inches, is nailed to the hip over the sheathing paper or felt, to support the hip roll. A copper clip *c*, a detail of which is shown in (*b*), is placed over the nail hole in the head of the hip roll, and a nail is driven through into the wooden support. The end of the clip is bent over the succeeding hip roll, as shown at *d* in (*a*), to hold the lower end in place. Portland cement mortar or elastic cement is sometimes used under the hip roll, as at *e*, to prevent any possible displacement.

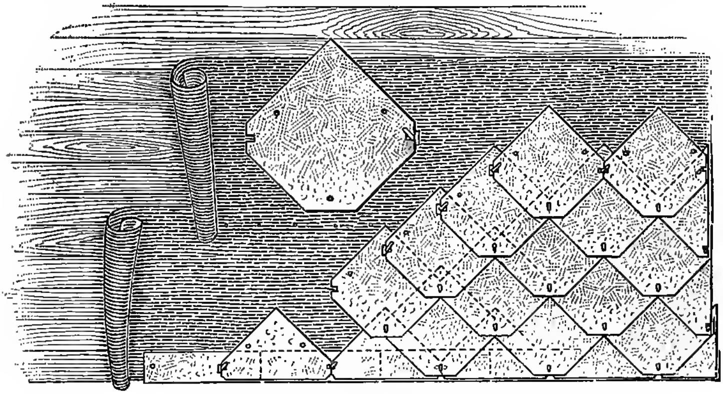


Fig. 52

87. Finish at Valleys.—Valleys for asbestos-shingle roofs differ in no way from those required for slate and shingle roofs. A copper valley is preferable, and the edges of the shingles which are laid over the metal should be bedded in elastic cement.

88. Finish at Ridges.—Metal or terra-cotta ridge rolls may be used on asbestos shingle roofs, the application being similar to that previously described. Another finish consists of using a ridge roll similar to that used on the hips, and applied in a similar manner.

89. Conical-Shaped Roofs.—For roofing conical-shaped roofs, shingles of the American type should be used.

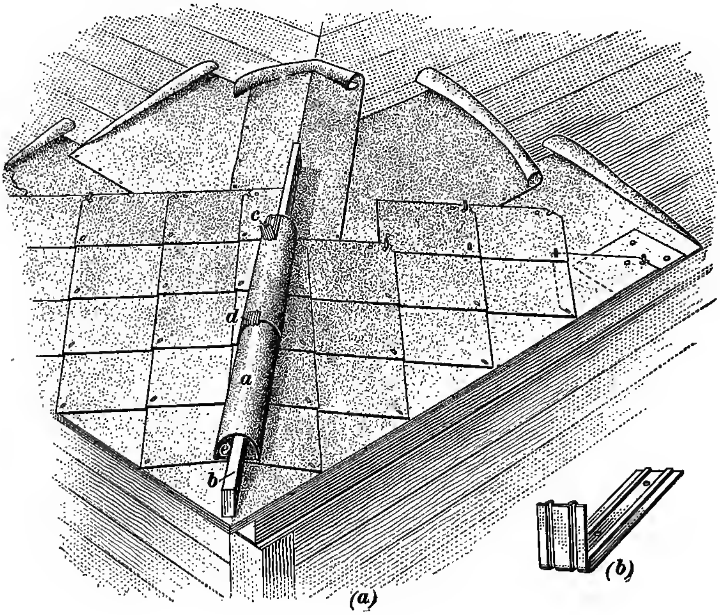


Fig. 53

as each shingle in each course must be cut and laid to radial line from the apex, as described for wooden-shingle roofs.

90. Flashings for Asbestos-Shingle Roofs.—As the asbestos shingles are thin plates similar to slate, and laid in a somewhat similar manner, the same methods of flashing are used. Copper flashings are preferably used.

CORRUGATED ASBESTOS SHEETS

91. The same materials used in the manufacture of asbestos shingles are also used in the manufacture of corrugated sheets to be used for the roofing and siding of buildings. These sheets are usually reinforced with woven wire mesh or perforated metal sheets, and are made in practially the same sizes as corrugated metal plates. Their application and use is the same as has been described for corrugated metal roofing.

TILE ROOFING

MANUFACTURE OF TILES

92. Tiles for roofing purposes are made of selected clays, which are burned so as to produce a dense, hard, vitrified, nonabsorbent product. These qualities must be obtained in order to have a tile that will be durable under the severe stress of weather, storm, frost, and hail. In order to make the tiles more resistant to the weather, they are sometimes glazed. This glazing may be accomplished by either of two methods, known as *salt-glazing* and *slip-glazing.*

Salt-glazed tiles are made by throwing salt in the fire while the tiles are being burned. This forms a hard, glass-like surface on the tiles that is not affected by gases, acids, or steam.

Slip-glazed tiles are made by covering the tiles with another clay known as *slip,* and baking it on. The slip may be made so as to produce different colors on the surface of the tiles which conceal the real color.

STYLES OF TILES

93. Tiles for pitched roofs may be obtained in five general styles, namely: *shingle,* or *flat, tile; Spanish,* or **S**, *tile; Mission,* or *half-round, tile; Roman,* or *pan, tile;* and *interlocking,* or *French, tile.* Tiles used to pave flat roofs are commonly known as *promenade tiles,* and have been described.

94. Shingle Tiles.—Tiles that are flat, and laid on the roof in the same manner as slates, are called *shingle tiles.*

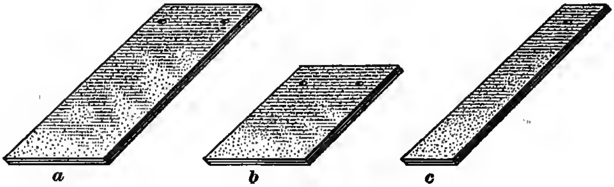


FIG. 54

These tiles are made with square butts as shown in *a, b,* and *c,* Fig. 54, and also with fancy butts, as in Fig. 55. A standard tile is shown in Fig. 54 at *a,* a starter at *b,* and a split, or half, tile at *c.*

In Fig. 55 the tile shown at *a* is a *square tile;* at *b,* a *round corner;* at *c,* a *round end;* at *d,* a *hexagon;* at *e,* an *octagon;* at *f,* a *scallop;* at *g,* a *gothic;* at *h,* a *Grecian,* tile. The tiles shown at *i* and *j* are called *Persian* tiles.

These tiles are generally made to lay on board roof and are perfectly flat. They may also be made with a lug, as shown at *k,* Fig. 55, in which case they are supported on battens, or lath, and are nailed through the holes *l.*

In Fig. 56 is shown a view of the tiles as laid. It is, of course, not customary to lay so many patterns on any one roof. The surface of a roof is generally laid in one pattern. Bands of four or five courses of a different pattern may be laid, however, to break up the uniformity of the roof.

95. Spanish Tile.—Spanish tiles are illustrated in Fig. 57. That shown in (*a*) is a single tile, and in (*b*) a group of tiles as they would appear on a roof. From their shapes they are sometimes referred to as **S** tiles. The edges are

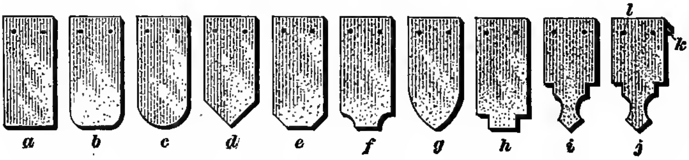


FIG. 55

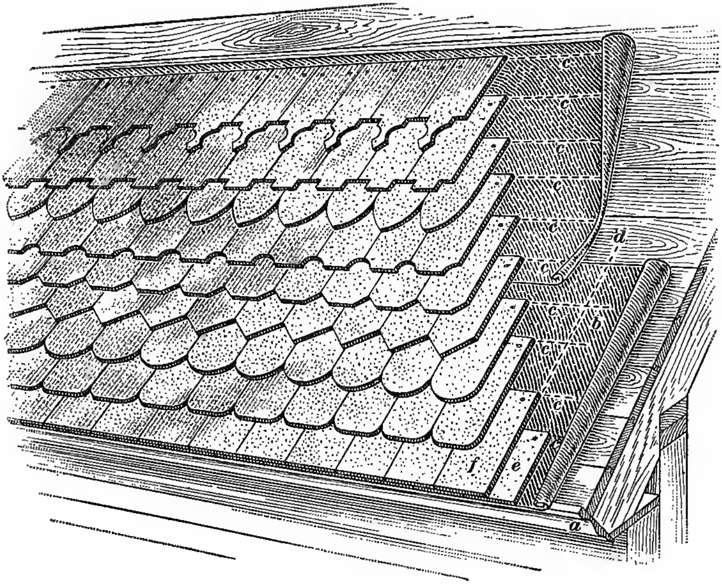


FIG. 56

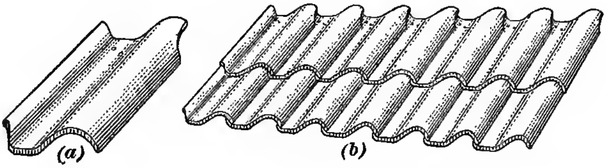


FIG. 57

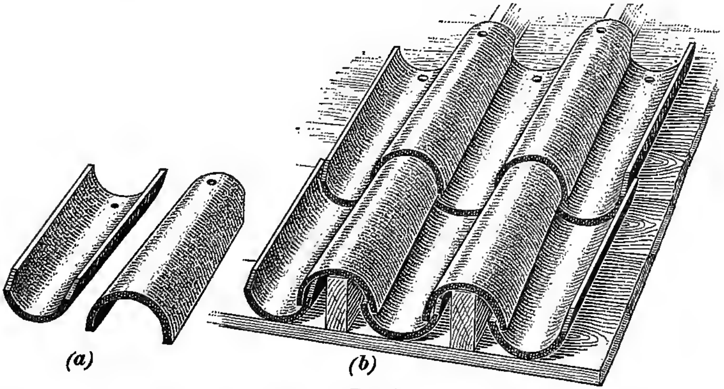


FIG. 58

designed to lap over each other, and the butt of each tile extends down on the tile below so as to cover the nail heads, and prevent the entrance of water.

96. Mission Tile.—A form of tile used on the old Mission buildings in California is shown in Fig. 58. The single tiles are shown in (*a*), and a portion of the finished roof in (*b*).

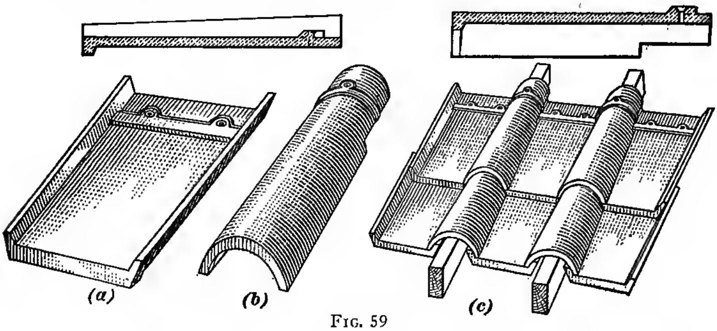


FIG. 59

97. Roman, or Pan Tile.—The form of tile shown in Fig. 59 is known as the Roman, or pan tile, so-called from the shape of one of the pieces of tile shown in (*a*). These pieces are laid flat on the roof and the joints between them are covered with pieces as shown in (*b*). A portion of a finished roof laid with these tiles is shown in (*c*). Cross-sections of both parts of the tile are given at the top of the figure.

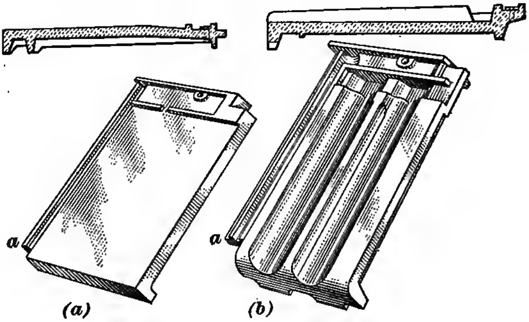


FIG. 60

98. Interlocking Tile.—Interlocking tiles are illustrated in Fig. 60. These tiles have especially designed joints which cause them to join together closely at the sides, tops, and butts. The joints *a* in (*a*) and (*b*) are designed to prevent snow and rain from being blown through the joint, as well as to lead off water that falls on the joint.

Interlocking tiles may be obtained in a great variety of patterns. Two forms of these tiles are shown in Fig. 60, in which (*a*) has the effect of a shingle tile, and (*b*) is known as a French tile. Immediately above (*a*) and (*b*) appears a cross-section of each kind of tile.

99. Promenade Tile.—Rectangular tiles of burned clay, used for surfacing flat roofs where there is apt to be considerable walking or rough usage, are known as promenade tiles, and their use and method of laying have been already described.

100. Sizes of Tiles.—The thickness, as well as the length and width of roofing tile, varies with the type and style, and with the various manufacturers. Tiles are seldom made less than $\frac{3}{8}$ inch thick, and some are made as much as $\frac{3}{4}$ inch. Promenade tiles are usually $\frac{7}{8}$ inch thick. The width exposed to the weather varies from 4 to 9 inches, while the gauge varies from 5 to 12 inches. There is a slight variation in the sizes of tiles of the same type due to shrinkage during the burning process, but in most cases this variation does not affect the gauge or laying width.

101. Weight of Tile.—There is a wide variation in the weight of different types and styles of roofing tiles. Some tiles weigh as little as 700 pounds to the square. This is due to the design, in which, as in interlocking tile, there is a minimum of cover, both at the sides and the top. In other types of tile, such as the shingle tile, the weight, due to the lap and double thickness of the tile, may be as much as 1,900 pounds to the square.

102. Trimmings.—In addition to the regular shapes of tiles just described, special tiles are necessary to complete a tile roof. These tiles may be described as *trimmings*, and include eaves closures, ridge closures, gable rakes, hip rolls, ridge rolls or crestings, ridge terminals or finials, closed-end ridge rolls, deck molds, etc.

Examples of these trimmings, such as would be used in connection with Spanish or **S** tile, are illustrated in Fig. 61.

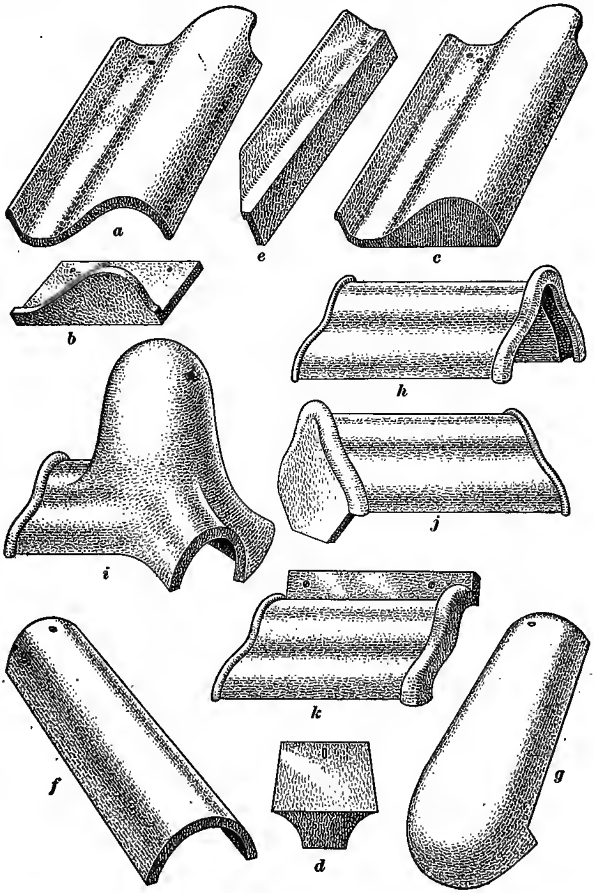


Fig. 61

Corresponding sets of trimmings are manufactured for all other types of tiles that have been described but will not be shown here. They may be seen in the catalogs of the various tile manufacturers.

At *a* in Fig. 61 is a regular Spanish tile, such as is used to cover the main surfaces of the roofs. Similar tiles are shown at *a* in Fig. 62.

At *b*, Fig. 61, is an *eaves closure* which is used to fill in the space under the first row of tiles. This is also shown at *b* in Fig. 62.

At *c* in Fig. 61 is a regular tile, the end of which has been closed. It is used as a starter, in which case it is not necessary to use an eaves closure. This tile is shown in Fig. 62 at *c*.

At *d* in Fig. 61 is a *ridge closure, or top fixture,* which is used over the top of the tiles at the ridge, as shown at *d* in Fig. 62. This closes the opening between the regular tiles at the ridge and forms a continuous seat for the ridge tiles *h*, Fig. 61.

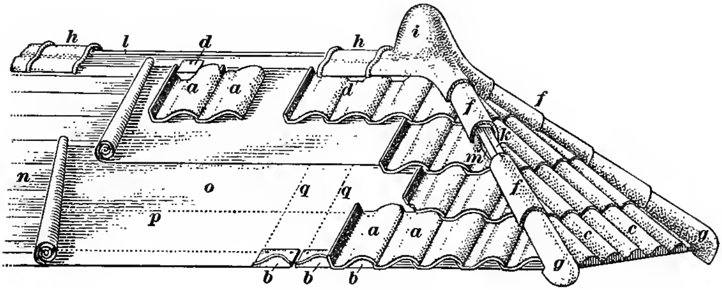


FIG. 62

At *e*, Fig. 61, is a *gable rake,* or *barge tile,* which is designed to be laid under the edge tiles at a gable. It extends down over the edge of the gable, and extends up under the regular tiles, and prevents the rain from driving under them. This tile is made in rights and lefts to fit at both sides of the gable.

At *f* in Fig. 61 is shown a *hip roll* which is laid over a wooden strip which is secured to the roof boarding. This is illustrated in Fig. 62, which shows a hip tile at *f*, as well as the wooden strip *k* to which this tile is nailed.

At *g* in Fig. 61 is shown a *hip starter,* the application of which is illustrated in Fig. 62 at *g*. These hip starters and hip rolls cover the regular tiles which are cut off against the wooden strip, as shown in Fig. 62 at *m*.

At *h* in Fig. 61 is a section of *ridge roll,* or cresting, which fits down over the top of the regular tiles and the ridge closures, as shown at *h* in Fig. 62. The ridge roll is nailed to a wooden strip *l* that is secured to the roof, and which shows under the ridge rolls.

At *i*, Fig. 61, is a ridge terminal, or finial, which is shown in position on a roof at *i* in Fig. 62.

At *j* in Fig. 61 is a *closed-end ridge roll,* which is used when the ridge roll terminates at a gable. The closed end at the left prevents water from being driven under the ridge roll.

At *k* in Fig. 61 is a deck mold, which is used as a top finish between a pitched roof and a flat roof or deck. It may also be used as a top tile when a pitched roof meets a vertical wall. The upper part in which the nail holes are formed must be covered either by other tile or by flashing.

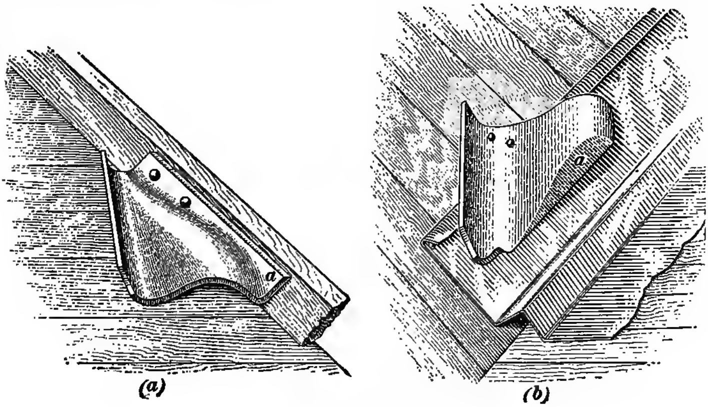


FIG. 63

In Fig. 63 (*a*) is shown a form of tile that is especially made to fit closely against a hip, and is used instead of a plain roof tile that is cut to fit in this position. Such tile must be made to fit the top of each vertical line of tile where it meets the hip, as at *m* in Fig. 62 and at *a* in Fig. 63.

In Fig. 63 (*b*), is shown a similar special tile that is molded to form a starter in a valley. Each piece must be especially molded, and the end *a* closed so that rain and snow will not enter beneath the tiles.

LAYING TILES

103. Preparation of Roof Surfaces.—Tiles are best laid on a boarded surface, as in Fig. 62, and in Fig. 64 (*a*), but are also laid on battens. The battens may be nailed on top of the roof boards, as shown at Fig. 64 (*b*) and (*c*), or directly to the rafters of the roof. In fireproof construction, when the roof is formed of structural iron, battens of angle iron, as at *b* in (*d*) are used, and the tiles are wired to them.

When tiles are laid on boards, as shown at *n* in Fig. 62, the boards should be from 6 to 8 inches in width, and matched, and should be covered with two thicknesses of single-ply, or one thickness of double-ply, felt as shown at *o*. This felt should be lapped over the valley and gutter linings, and turned up 6 inches against vertical walls, and also doubled over hips and ridges.

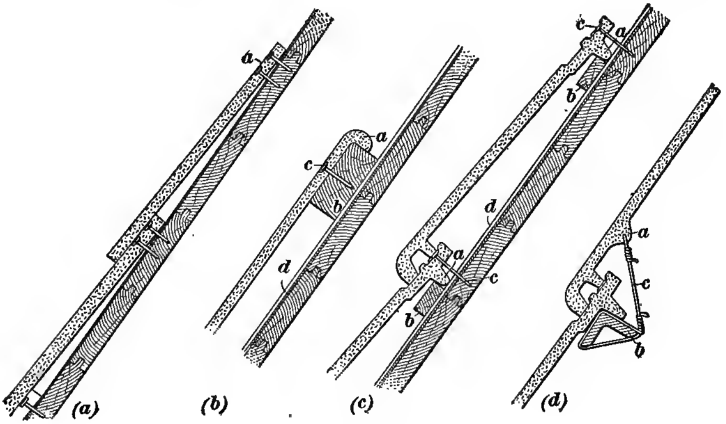


Fig. 64

Battens may be nailed to the roof boards as shown in Fig. 64 (*b*) and (*c*), and used to support the tiles. In such cases the roof boards should be covered with waterproof felt. The roof should then be stripped vertically with ordinary plastering lath, as shown at *d* in (*b*) and (*c*). On top of these laths the battens *b* are nailed. The space between the battens and the paper allows water, which might find its way under the tiles, to run down to the gutter over the felt. The tiles, when laid on battens, are provided with lugs *a* which catch over the battens, the nails *c* are then driven, and the tiles are thus securely held in place.

Hips and ridges are provided with strips upon which the hip and ridge rolls are nailed. This is necessary with tiles such as the Spanish or Mission types, but is not required with shingle, or flat, tiles.

104. Fastening Tiles to the Roof.—As shown at *a* in Fig. 64 (*a*), shingle tiles are simply nailed to the boarding. When the tiles are supported on angle-iron battens, as in (*d*), they are wired to the batten as shown, the wire passing through the hole *a* in the tile. Copper or composition nails or wire *c* are preferable for fastening tiles, as these materials are practically proof against corrosion. Galvanized nails are sometimes used as they are cheaper.

105. Laying Shingle Tiles.—The general method of laying shingle tiles is shown in Fig. 56, and it will be noted that the method closely resembles that already described for laying slate roofing. The eaves molding *a* is raised above the plane of the roof, an amount equal to the thickness of the tile, to form a fillet, and the roof boards are covered with two-ply roofing felt *b*, which extends down to the outside edge of the eaves molding. Chalk lines *c* and *d* are struck both horizontally and vertically for guide lines for the top edges of the tiles and for the vertical joints. Experienced roofers sometimes strike only every eighth or tenth vertical line, trusting to the eye to keep the courses straight between.

The first course of tile laid is the under-eaves, or starter, *e*, Fig. 56, the top of which is laid to the first line *c*. The next is the first full course *f*. It is customary to carry two or three courses through together. When these are laid the next two or three courses are started.

Shingle tile may be laid from either the right-hand or from the left-hand end of the roof. Where there are gable ends or vertical walls, it is usual to start at those places with full tile in one course and a half tile in the next course, and so on alternately until the ridge is reached, breaking joints vertically in every course, and working toward the hips or valleys. The hip and valley tiles are usually cut on the job, although for the best work they should be cut at the place of manufacture before burning. Shingle tiles permit changing the gauge or exposure where the design of the roof requires it.

106. Laying Spanish and Interlocking Tile.—Spanish and interlocking tile of the types shown must be laid from right to left as shown in Fig. 62. Horizontal lines *p* and vertical lines *q* are struck for guides. In order to come out with whole tiles at the gable ends it is sometimes necessary to lay the course out on the roof before the actual laying is commenced, or to measure back from the gable a distance equal to a number of whole tiles. Some forms of interlocking tile are made in one-quarter, one-half, and three-quarter widths, in order to make neat finishes at gable ends, against walls, and in similar places. Great care must be taken with interlocking tile, both with the horizontal and with the vertical lines, as the tiles must be laid without breaking the lock of the tile. As tiles vary somewhat on account of the heat applied in burning, it is necessary to examine the tile carefully to determine the correct gauge and width. At the ridges the spacing must be done carefully in order to preserve the neat appearance demanded in good work.

107. Laying Mission and Roman Tile.—Mission and Roman tile of the types shown may be laid from either the right or from the left. With some types it is customary to lay the cover pieces on wood strips placed the proper distance apart on the roof, as shown in Fig. 58 (*b*). These strips should be applied after the roofing felt is in place. The roofing felt is, however, omitted in this figure. The spacing of these strips should be carefully done, in order that the lines of the tile may be kept perfectly vertical.

108. Conical Roofs.—The tiles for conical roofs must usually be made to suit the pitch and curvature of the roof. Shingle tiles may be cut on the sides so as to make them conform with the radial lines from the apex, in the same manner as described for wooden shingles and slate. If, however, the butt of the tile is made with a pattern, this method cannot be used, and special tile must be made. Exact measurements must be furnished to the manufacturer so that he can cut the tile to the shape required; and from four to six weeks must be allowed for making and burning the tile. When tiles are made specially, the manufacturer cuts a number in the under side of the green tile, and supplies a drawing showing the location of each numbered tile. This permits the roofer to pick out the tile for every course.

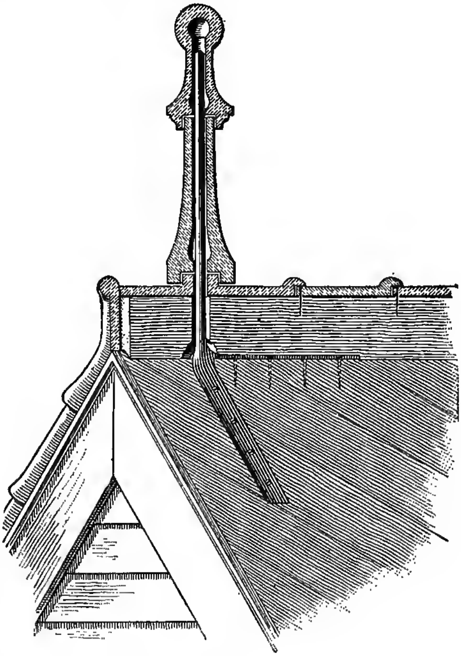


FIG. 65

In laying tile roofing on conical surfaces, lines should be drawn from the apex to the eaves, and the sides of the tiles must be fitted to these lines.

109. Tile Finials.—Heavy hip or gable finials should be well braced with brass or galvanized-iron rods, and the sections of the tile finials should be securely wired or anchored to these braces, and well cemented with elastic cement. If necessary, a wooden framework should be built on the roof to support the finial, so that none of its weight will come directly on the roof tile. For a vertical finial, a tripod may be made and secured to the roof as shown in Fig. 65, the ends of the iron being held in place with brass or galvanized-iron screws. For an overhanging hip finial, the brace may be constructed as in Fig. 66, the top of the rod being carried to the ridge of the finial. Where the finial is on the apex of a tower, the brace may be constructed with a galvanized-iron rod of dimensions to suit the size and shape of the finial, and stiff enough to resist the wind pressure. The construction of such a brace is shown in Fig. 67.

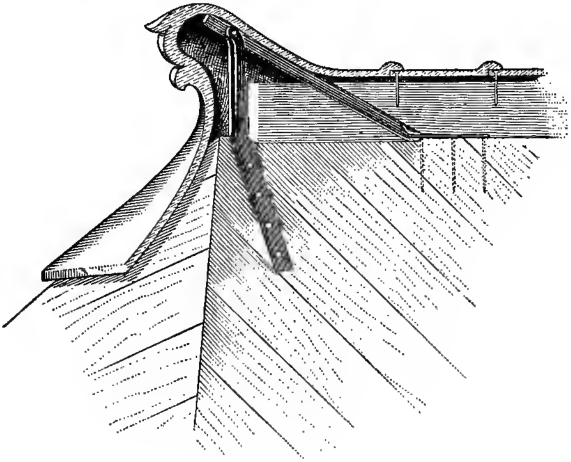


FIG. 66

110. Flashings for Tile Roofs.—Tile roofs are nearly always laid with open valleys, and the same precautions are to be observed as with slate roofs. The valley should be formed with a **V** crimp, to prevent water from passing under the tiles. Copper is especially desirable for valleys in tile roofs, on account of its durability.

Hips and ridges do not require flashings as the joints at those places are made tight with elastic cement. With some forms of tile, Portland cement mortar is used for pointing up between the hip and ridge tiles and the roof tiles.

Where a roof surface comes against a parapet, gable, or other vertical wall, the junction should be flashed with 14-ounce or 16-ounce copper, nailed to the roof at the upper corner only. This flashing should be lapped on the roof a distance equal to the width of a tile, and should be carried up against the wall 6 or 8 inches. This flashing should be counterflashed with copper, in the same manner as described for slate roofing.

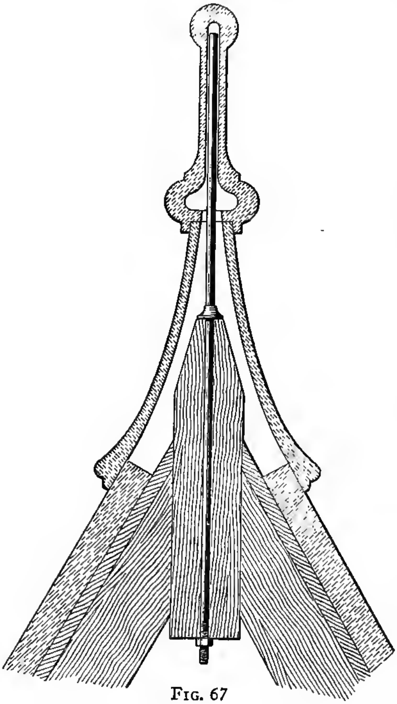


FIG. 67

111. Snow Guards With Tile.—A form of snow guard that is used with slate is shown in Fig. 12. This form can also be used with shingle tile. In Fig. 68 is a similar snow guard, but one that is designed to be used with Spanish, Mission, or Roman tile. The point *a* is driven into the roof boards, with the part *b* resting on the boards. The part *c* must be sufficiently long to permit the part *d* to be above the tile, and the part *e* to extend entirely above the highest portion of the tile. The snow guard may be made of galvanized iron or copper.

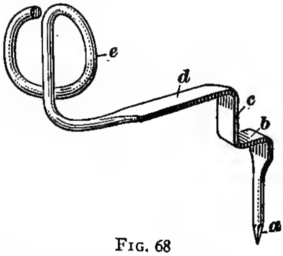


FIG. 68

CEMENT-TILE ROOFING

GENERAL

112. Cement tiles are made of Portland cement, sand, ingredients that make the tiles waterproof, and rod or wire-mesh reinforcement to give the tiles sufficient strength. They are made in a variety of shapes and sizes, from small slabs in the form of clay roofing tiles, to very large slabs designed for roofs of factories and warehouses. Tiles for the latter purpose are made usually about 26 inches wide, and from 24 inches to 64 inches in length. (When in place they cover 24 inches in width, and from 20 inches to 60 inches in length. These large tiles are made from $\frac{7}{8}$ inch to $1\frac{1}{4}$ inches thick, which makes a heavy roofing material, weighing from 1,200 to 1,500 pounds to the square. For the purpose of lighting the interior of buildings the tiles are sometimes made with glass plates inserted, as at *a* in Fig. 69. Wire glass is preferable for this purpose, as the wire acts as a reinforcement, and prevents damage from pieces of glass falling from the roof, if the sheet should be broken.

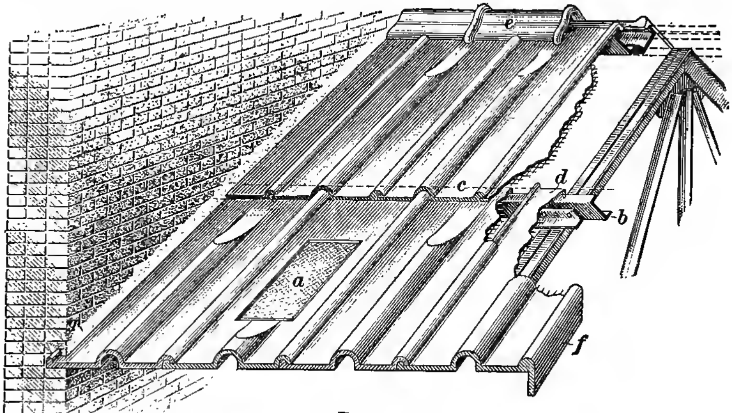


Fig. 69

LAYING CEMENT TILES

113. Tiles that are made in the same form as clay roofing tiles are laid in a manner similar to that used for clay tiles, as already described.

The larger sizes of cement tiles are laid usually on purlins of either wood or steel, without any sheathing or felt. A typical method is shown in Fig. 69. Purlins *b* are spaced so that the tile will lap 4 inches at the head, as at *c*. The tiles are laid with the hook edge *d* over the purlin, the weight of the tile being sufficient to prevent displacement by the wind. Where the weather is severe, lugs are sometimes cast on the inside or lower side of the tile, by which the tile may be wired or attached firmly to the structural members of the building. The tile lap, or interlock, on the sides, prevents water from entering the joint, while the 4-inch lap at the ends of the tile prevents water from finding its way through.

114. Finish at Ridge.—At *e* in Fig. 69 is shown a cement ridge piece which may be used with cement tile. The separate pieces of ridging interlock in the same manner as the sides of the roof tile. The weight of the ridging is sufficient to prevent displacement, although the pieces may be fastened or cemented down if desired. The wings of the ridging fit so closely to the roof tile that pointing is unnecessary, although sometimes the joint is pointed up with Portland cement mortar.

115. Finish at Gable Ends.—Where the roof extends over the side or gable wall, a special roof tile having an apron, as at *f*, Fig. 69, may be used. These gable tiles are made in rights and lefts.

116. Finish Against Walls.—A roof of cement tiles may be made water-tight at the side walls by extending the tile into a recess from 2 to 4 inches deep, left in the wall by the mason, as shown at *g*, Fig. 69. The recess is afterwards filled with Portland cement mortar.

SHEET-METAL WORK

USES OF SHEET METAL

1. The greater part of sheet-metal work used in building construction is employed for the following purposes:

1. For covering and flashing roofs and their intersections so that the roofs may conveniently be made water-tight.

2. For wall covering and the formation of columns, cornices, balustrades, and string and molded courses. In some cases, the entire outer surface of the walls of a building is covered with sheet metal, the material being made to resemble masonry or brickwork, an effect produced at low cost. Frame buildings may also be covered with sheet metal in order to render them less liable to fire from adjacent structures.

3. In forming gutters, valleys, or other water channels that are graded down to certain points of outlet, so that the rain that falls on the roof may be conveniently drained away, thus preventing the roof water from being shed on the ground around the building.

4. For conductor pipes, sometimes called leader pipes, which are commonly secured against the outside walls of a building to connect the lowest points of the roof gutters with an underground drainage system, or simply to a drainage above the surface of the ground, so that the roof water may flow freely away from the gutter.

5. For covering domes and lanterns, and in forming crestings and finials.

6. For interior decorations, such as the covering of walls and ceilings where first cost is an important factor; or, for

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the covering or formation of the inside trim, doors, windows, casings, etc.

7. For flues and other conduits commonly employed for purposes of ventilation.

While there are other positions and features where sheet metal may be employed, a thorough knowledge of the foregoing should enable any one to reason out and solve any special problem that may present itself.

EXTERIOR SHEET-METAL WORK

INTRODUCTION

2. The general subject of sheet-metal work for roof coverings, flashings, etc., is treated in *Roofing*, consequently, this portion of the subject will not be considered in this Section.

The kind and class of exterior sheet-metal work required will of course depend on the character and purpose of the building. Mills, factories, workshops, warehouses, etc. are often covered with galvanized sheet iron in the plainest possible manner, with no pretensions to artistic treatment, while store and office fronts are often covered with sheet metal bent and formed into elaborate moldings, or pressed and stamped into ornamental details, which are grouped so as to form decorative features.

3. Generally speaking, sheet-metal coverings for buildings are imitations of brickwork or masonry, and when properly arranged and attached to a good solid backing and carefully painted, they make, for some time, successful deceptions.

Sheet-metal fronts and other wall coverings are employed only when the desire for ornamentation exceeds the owner's willingness or capability to pay for the genuine article. From a speculative point of view, they may be paying investments, provided that the metal is protected against corrosion; but from an architectural or engineering standpoint they are utter failures.

WALL COVERINGS

4. Wall coverings may be classed as plain and ornamental. Plain wall coverings are used chiefly on buildings intended for manufacturing purposes and for such structures as are erected for temporary use; while ornamental coverings are generally used on the fronts of cheap city buildings, such as warehouses, stores, theater fronts, etc.

5. The sheet metal employed for wall coverings is usually galvanized sheet iron or steel, the sheets being either *plain*, *crimped*, or *corrugated.*

Plain sheet iron is seldom used except for the most ordinary work, where appearance is not at all considered. The sheets are simply nailed to a backing of matched lining or ordinary sheathing, the object usually being to prevent the building from readily becoming ignited, should an adjacent building be on fire.

The chief objection to plain sheet-iron siding is that the metal will bulge and become distorted in many ways, until the whole side of the building will actually appear to be covered with large blisters.

6. Crimped sheet iron is superior to plain sheet iron for covering large flat surfaces, because the crimping helps to prevent the sheets from bulging, and thus, to a certain extent, avoids the blistered appearance so pronounced on plain sheet-iron siding. A clipping of crimped sheet metal is shown in Fig. 1. The sheet is crimped by being passed through ribbed or roughened rollers, which give it the appearance of being slightly corrugated. Crimping the sheets makes them stiffer than they would otherwise be. The sheets can be bent to any desired angle without breaking the material, which is impossible with corrugated iron. Beside being used as a wall covering crimped iron can be used for cornices, door and window casings, friezes and panels.

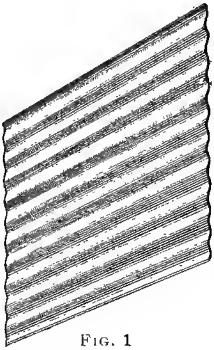


FIG. 1

Crimped sheets may be nailed to furring strips, or to studs or posts set at from 12 to 16 inches between centers, provided that the grooves run at right angles to the strips or studs. Thus, if furring strips were nailed on the studding, the grooves would be vertical; but if the sheets were nailed directly on the studding, the grooves would be horizontal. It is best, however, in every case to provide a solid flat backing for crimped sheet-metal work.

7. Corrugated sheet iron is preferable for siding where there is an extensive, unbroken surface. The corrugations not only strengthen the sheets, and thus enable them to be attached to furring strips as far apart as 4 feet, but they also relieve, by the play of light and shade, the monotony incident to a flat surface.

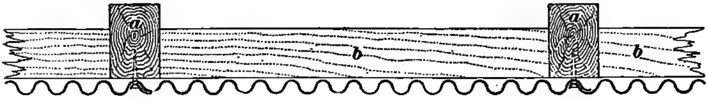


FIG. 2

Corrugated sheet iron should always be fastened with the corrugations running vertically, not so much for appearance as to obtain a perfectly water-tight siding with ordinary lap joints. Fig. 2 shows the method of forming vertical joints. The corrugations are simply lapped and the two sheets are nailed to the posts, or studs, *a*, *a* with flathead, galvanized-iron nails, as shown in the illustration. The top edge of each sheet is nailed to cross-pieces—sometimes called "nailers"—*b*, *b* that are spiked or framed in between the posts. The horizontal joints of the sheets are lapped as shown in Fig. 3; cleats are riveted on as shown at *a*, to bind the lower end of the sheet so as to make a close joint and also allow for

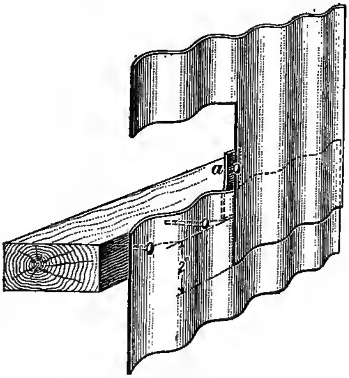


FIG. 3

expansion and contraction of the sheets. The top sheet should lap over the nails at least 2 inches.

Corrugated-iron sheets are often fastened to sheathed walls, and the common practice is to nail them all around the edges, but, in this case, expansion and contraction soon loosen the sheets either by drawing the nails or by tearing the nail holes. The plan of attachment just described, and illustrated in Fig. 3, is to be recommended even when the sheets are fastened to a flat surface.

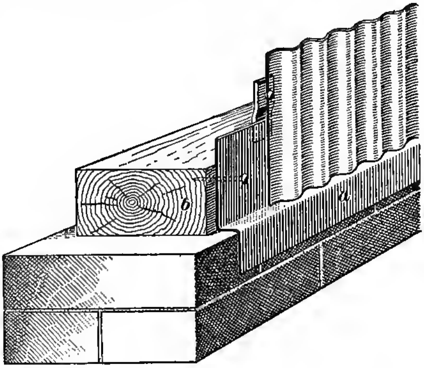


FIG. 4

8. Fig. 4 shows how the corrugated sheets may be put on at the base of the framework. A *base strip a*, made in the form of an offset, is securely nailed to the wooden sill *b*, the strip being flanged so that it may cover the exposed portion of the wall. The sheets are clamped to the top edge of this strip with cleats 1 inch wide by $\frac{1}{8}$ inch thick, similar to that shown in Fig. 3.

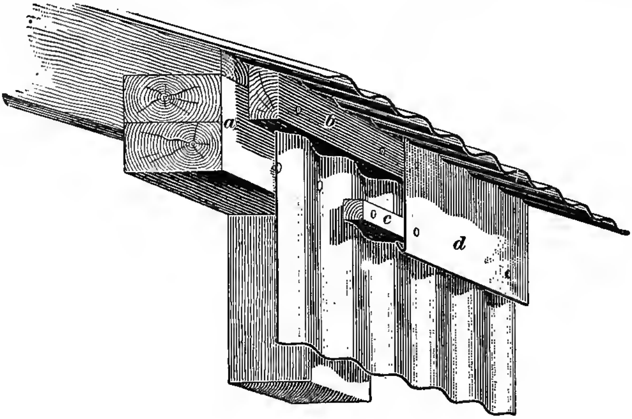


FIG. 5

9. Fig. 5 shows how the sheets are finished at the eaves. The top edges of the sheets are nailed to the plate *a*. A strip of wood *b* about $1\frac{1}{4}$ inches thick, cut on one edge to fit the profile of the corrugations of the roof, is nailed to the upper edge of the plate above the sheets, and another strip *c* of the same material is nailed to the lower edge of the plate. A facia of crimped sheet iron *d* covers both strips and forms a drip at its lower edge, as shown. This arrangement makes a neat, water-tight, and wind-proof connection between the siding and the roof.

10. Fig. 6 shows the finish at the corners of the building; this makes a water-tight junction and presents a neat appearance. Since the corrugated iron is laid against the framework, it is necessary to nail $\frac{7}{8}$-inch wooden strips on the outer faces of the corner post *a*. The corrugated iron butts against the edges of these strips, and a crimped sheet-iron corner piece is sprung over and locked into the corrugated wall sheet, as shown.

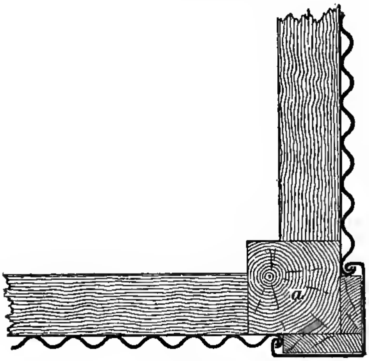


Fig. 6

This arrangement can also be used around any window or door opening. The arrangement shown in Fig. 4 may also be used over the lintels of any door or window opening.

11. Corrugations in common use measure about $2\frac{1}{2}$ inches, from center to center, and are about $\frac{3}{4}$ inch deep.

Black corrugated iron should always be painted with the best quality of metallic paint before it is secured in place.

12. **Stamped siding** is most commonly employed for covering large flat surfaces of outer walls, the sheets being pressed to such a shape that they resemble *rock-faced*, or *tooled*, stonework or brickwork. This siding is stamped in plates 10 feet long by 2 feet wide, and the plates are sold by the lineal foot. Like crimped sheet metal, it is nailed to furring strips, to ordinary sheathing, or to brick walls, the vertical joints being lapped and closely nailed.

Particular care should be taken to lap all the vertical joints in sheet-metal work, so that the heaviest rain storms will blow with the laps and not against them. It is noticeable in nearly every district that the strongest winds and greatest rain storms nearly always blow from certain directions; these directions should be determined, and the sheet-metal work should be arranged to prevent the rain from blowing into the seams.

Brick walls should always be thoroughly furred to receive the sheet-metal work. It is a mistake to suppose that sheet-metal work can be securely nailed into the joints, because expansion and contraction will very soon loosen the fastenings.

CORNICES

13. Sheet-metal cornices are made in such a variety of patterns, in such a wide range of sizes, and are required to be placed in such a diversity of situations, that there must be a great variation in the methods of construction. Very many designs, however, correspond as far as having moldings continuous throughout their lengths. All are supported by projecting brackets or lookouts. The joints, shape, and material of the cornice proper, and the construction of lookouts, are the particular features in cornice work that will be considered here.

As a rule, cornices are made at the cornice factory, according to drawings and specifications, and are shipped in parts to the building.

Brackets, modillions, dentils, etc. are usually secured to the cornice at the factory. Trusses and check, or stop, blocks are shipped in separate packages. Thus it will be seen that the cornice setter or tinsmith is only required to assemble the several parts and erect them in place on proper supports. The supports in general use are wood or iron, the latter being employed in the better class of buildings.

14. Cornice Erection on Wooden Supports.—In Fig. 7 are shown the parts and joints of a sheet-metal cornice as ordinarily constructed in small sections on a brick wall. The foot-molding *a* is fastened to, and supported by, a board and wooden lookouts, the lower member being allowed to hang down below the reglet, or groove, that runs along the joint of the brickwork at the under side of the lookouts. The top of the foot-molding enters the reglet in the next joint above. The paneled frieze *b*, between the trusses, or brackets, *c*, is made up in one piece, the edges being doubled over and secured into reglets as shown. The modillion course, which generally includes the small moldings above and below the plain surface from which the modillions project, is attached to the brickwork in a similar manner and is secured in place with a long, narrow, metallic wedge. If the cornice is erected while the walls are being built, the upper flange of each piece is usually bent over far enough to be safely bedded in, the lower edge of the sheet above being bent over and pushed into the same joint as the work progresses. The soffit *e* may be bent up out of the same piece

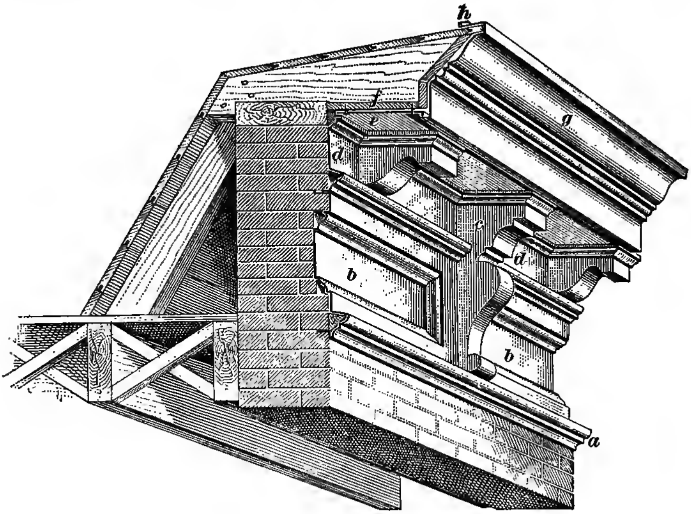


Fig. 7

with the bracket molding. The drawing, however, shows it separate, and secured to the board lining *f*.

The *crown molding g* is bent over the top of the roof boards, leaving an edge turned up, as at *h*, for easy connection to the sheet metal of the roof. The lower edge of the crown molding should be made to form a drip, as shown, and should be securely nailed to the board lining *f*.

The brackets and trusses, which are hollow and built up from stamped sheet metal, are riveted and soldered in position. It is difficult, however, to properly attach them when the cornice is put up in sections, as shown, so it is advisable to have these projections riveted and soldered on before the cornice is erected. In the construction of cornices, particular care must be taken to avoid pockets in which water may accumulate. If it is suspected that a water-tight pocket exists, a small hole should be punched at the lowest point to allow any water to drain out. If this is not attended to, these pockets may fill with water, freeze, and burst.

15. Another plan for fastening cornices to brick walls is to spike boards against the face of the walls, put the cornice on top of the boards, and nail it in place. The former method, however, is preferable, not only because the nails will show by the latter method, but chiefly because the boards are likely to warp and consequently cause the cornice to become distorted and loosened.

The cornice work shown in Fig. 7 is attached to a brick building with a flat roof. The roof pitches down to the back of the building and the conductor pipes, of course, are in the rear. When the roof pitches in the direction of the cornice, a gutter is usually formed at the back of the crown molding.

16. Iron Supports.—It is comparatively easy to fasten a sheet-metal cornice to a wooden building, or even to woodwork that is spiked to brick buildings; but it is considerably more difficult to properly fasten a cornice to brick, stone, terra cotta, or to the structural ironwork of modern fireproof buildings.

Fig. 8 shows a system of bracing well adapted for a cornice at the top of a brick wall. The framework or bracing shown, which is mostly composed of angle irons, should be built into the wall. These frames should be placed from 2 to 4 feet apart, according to the projection of the cornice. The cornice is sometimes bolted to the framework after the wall is finished.

The strongest and best plan, however, is to attach the iron frames to sections of the cornice that are about 14 feet long, hoist these sections, and set them on the wall when it has been leveled to the required height, as at *a*. When lined up and in proper position, the frames are tied temporarily in place to keep the cornice from toppling over until the brickwork *b*, *b* is all filled in and has set. This mass of brickwork must be sufficient to more than counterbalance the weight of the cornice. If there is any danger of the cornice being too heavy for the counterweight, the legs *c* must each be tied separately to some beam or other rigid part of the building.

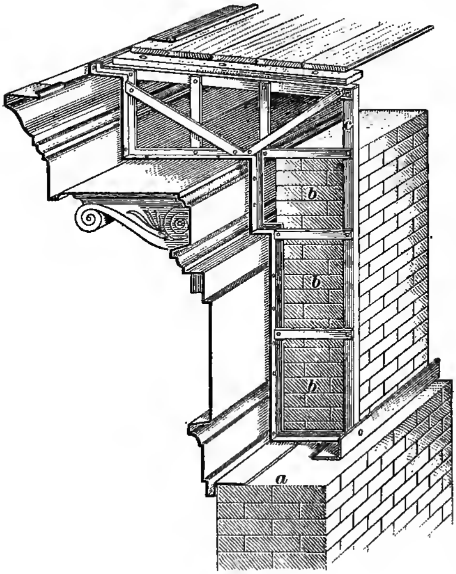


Fig. 8

There are, of course, many kinds of iron supports for cornices other than that shown in Fig. 8, but, with a little judgment, a lookout for any position can be designed. The principal points to be considered in such a design are: (1) to obtain a band of iron that will follow, in a general way, the contour of the cornice; (2) a means of bracing this iron band

and preventing it from changing its shape; (3) a means of rigidly securing the iron band to the building, iron beams, or columns, being preferable for anchoring points.

17. **Joints in Cornices.**—Different mechanics have different methods of making vertical joints in cornices; some of these are very neat, strong, and durable, while others should not be tolerated. The only two joints worthy of mention here are the *butt joint* and the *lap joint*.

18. A **butt joint** is shown in Fig. 9. The edges of the sheets *a*, *a* that form the cornice are trimmed perfectly square and straight, so that when brought together they will fit closely. A strap *b*, which is made from the same metal as the cornice, is then riveted the entire length of the vertical seam, and its edges are soldered to the back of the cornice, as shown. The rivet heads are all on the outside, and the process of riveting draws in the heads and makes them scarcely visible. The rivets should be as close together as possible.

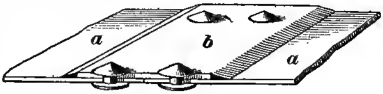


Fig. 9

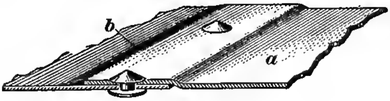


Fig. 10

Fig. 10 shows a **lap joint**. The sheets are lapped over each other a distance of 1¼ inches and then riveted closely. The back sheet *a* is dressed forwards to be flush with the other, as shown, and the back edge is then soldered, as at *b*.

19. Both of these joints are strong and durable. The butt joint, however, is neater than the lap joint. A first-class mechanic can make one of these joints so that a perfectly smooth surface will be obtained.

The *rivets* for galvanized-iron cornices should weigh 1½ pounds per thousand, for Nos. 24, 26, 28, and 30 sheet iron. The rivets for copper cornice work should weigh 1 pound per thousand.

20. Cornice seams, or horizontal joints, are also made in a variety of ways, but the following methods illustrate good practice when the joints must be made on the job.

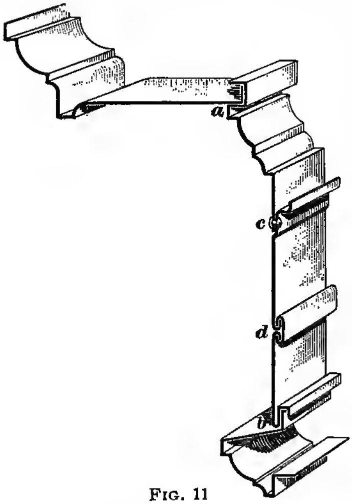


Fig. 11

Cup joints are shown at *a* and *b*, Fig. 11. The position of the copper in these joints shows how they appear when the cornice is being fitted up. After the cornice is lined up in place and the vertical joints are all made, the edges are bent over twice, thereby locking the seams. These joints are necessary only in large cornices.

When a seam must be made on a flat surface, such as on a wide frieze, either of the methods shown at *c* or *d* may be employed. The seam at *c* is lapped and riveted like that shown in Fig. 10; a stiffener, however, is bent at the back to keep the seam straight. This is the stronger seam of the two. It is preferable to that shown at *d* in places where rain will wash over it. When it is desired to form a very close horizontal joint, the *clinch seam* at *d* may be used. The edges of the sheets are bent over and butted together in position. A cap is then slipped over the seam as shown. When the work is all lined up, the seam is closed by flattening down the cap. This process draws the sheets together and makes a very close seam.

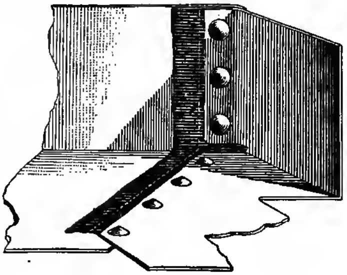


Fig. 12

21. Miters.—All miters in cornice work, pediments, and elsewhere may be classed as *lap miters* or *butt miters*.

Outside miters are made in different ways, but there are only two reliable methods. The first, or lap miter, is made by returning a $\frac{1}{2}$-inch flange on the inside of the miter, as shown in Fig. 12. This flange must be riveted closely and soldered on the inside. The chief objection to this miter is that the edge of the sheet is visible.

To make a close miter, it is necessary to bevel and butt the edges as shown in the butt miter, Fig. 13. In this figure, the edges of the copper are fitted closely together. A copper angle strap *a* is then riveted and soldered securely in the inside angle the full depth of the cornice. A few gussets are then riveted and soldered across the inner corners as shown. These gussets help to keep the cornice square during shipment and prevent the edges from being pulled apart by expansion and contraction. The method shown in Fig. 13 should be used on all first-class work.

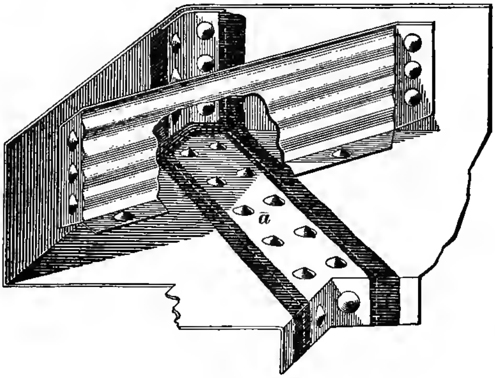


FIG. 13

Inside miters are made and reinforced in a similar manner, but owing to the fact that gussets cannot be used, it is advisable to rivet a reinforcing angle strap over the $\frac{1}{2}$-inch flange.

22. Iron-Beam Cornices.—In some buildings, the ironwork of the first story or "store front" does not project beyond the wall; and the iron beams, such as those over store windows, often require to be covered with a metal panel or cornice, or both combined.

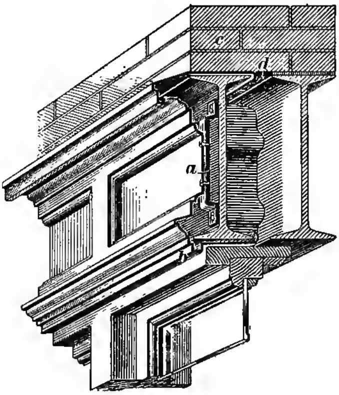


FIG. 14

Fig. 14 shows a *panel course* attached to an iron **I** beam. A series of bar-iron braces *a* are secured to the web of the **I** beam and the panels are fastened to them with countersunk screws, so that the heads will finish flush with the face of the panel. A rabbet is formed at *b* to cover the joint between the top of the window frame and the iron beam. When the beams are in place, and before the brickwork *c* is built thereon, the sheet-metal panel course is pushed over the face of the beam and doubled over at the back edge of the upper and lower flanges, as shown at *d*. The braces *a* thus merely support the frieze and prevent it from sagging. If desired, a plank instead of iron straps may be bolted to the web of the beam to support the panels.

23. String-Course Cornice.—A string-course cornice, or store cornice as it is often called because it is so commonly used over store fronts, is shown in Fig. 15. The lookouts are made of band iron $\frac{1}{4}$ in. × $1\frac{1}{2}$ in. and are tied into the brickwork at *a* and *b*, these ends being built into the wall. The lower ends of the lookout frames are continued down over the face of the beams and along under their lower flanges, and are then bent up at the back, as shown at *c*. An angle iron running the whole length of the cornice is bolted to the ends as shown at *d* and keeps them in place. A sloping platform of matched boards is screwed on the top of the lookouts. The sheet-metal work is bolted to the band iron in the usual manner, a soldered double seam with cleats is made at *e*, and the top covering enters the wall at *f*. An iron plate, either plain or ornamental, is usually secured at *g* to form the soffit of the beams over the opening.

After the beams are set on their columns, and before the mason begins to build on them, the cornice must be set in position. The cornice being set true and level, the mason finishes the wall up to the course *h*; then the flashing is put on, the top edge *f* being bent over about 3 or 4 inches, as shown. When this is finished, the mason proceeds to build the superstructure. If the wall is built before the cornice lookouts are ready, the anchors *a* and *b* must pass through the wall and be bent over at the back, and the flashing *f* must be let into the reglet and be batted with lead, the reglet being filled with mastic or other cement in the usual manner.

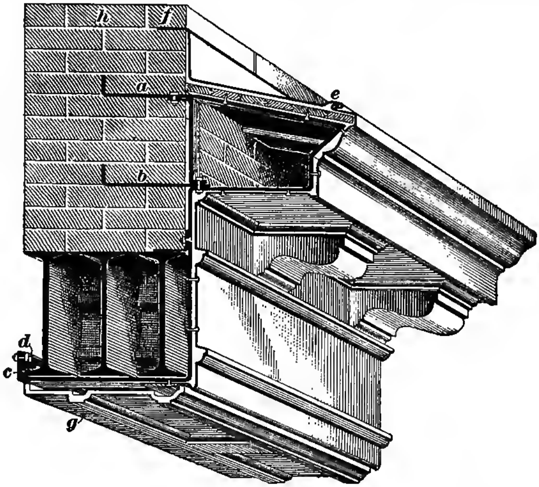


FIG. 15

24. In many cases, it is advisable to make the lookouts of cast iron instead of wrought iron, as, for example, when a very large number of small lookouts having the same shape are required. If the molding is small and extends as a belt, or string-course, around the building, it is certainly advisable to use cast-iron lookouts. The chief advantages of cast-iron lookouts are accuracy in the lines of the cornice, economy in construction, and durability.

Accuracy is insured when the cast-iron lookouts are properly lined up, because each lookout is a duplicate of the others, all of them being cast from the same pattern. Economy of construction lies in the fact that the labor of making the lookouts and of fitting the sheet metal to them is reduced to a minimum; and the durability lies in the fact that cast iron is less corrosive than wrought iron. Iron lookouts should always be coated with asphalt or other protective covering in order to prevent rapid corrosion.

25. Metals Used for Cornices.—Galvanized iron is commonly used for the cornices of ordinary buildings, and should be painted on both sides to protect it from corrosion. Sheet copper (cold-rolled) is preferable, however, in every case. The metal itself costs considerably more than iron, but the labor and other expenses relative to its construction and installation are about the same.

26. Copper cornice work does not require to be painted for protection. It is, in fact, better practice to leave the metal thoroughly scoured, clean, and uncovered, and allow the weather to slowly change its color. Copper sheet-metal work has naturally a dark-green tint, but it often takes a very long time to get that color. The time required depends considerably on the climate, the weather, and the composition of the atmosphere. Where the rain becomes acidified by falling through air charged with sulphurous gases, the color changes rapidly, but where it falls pure and clear, the copper changes color very slowly.

When it is desired to hasten the color, it is customary to produce an *artificial* color by washing the copper with acids. One method is to thoroughly scour all the copper work to remove any grease or acid spots, then wash the entire surface with a solution composed of 1 pound of sal ammoniac to 5 gallons of water. This solution should stand about 24 hours before it is applied. After the copper has been uniformly covered with the solution, it should be allowed to stand for a day or two and should then be lightly sprinkled with clean water. If the water is put on too freely, it will run in streaks. After a few days the copper work should have a beautiful and uniform greenish-brown color that will stand the weather. The same effect may be produced by using vinegar and salt in the proportion of ½ pound of salt to about 2 gallons of vinegar.

27. Soldered Seams.—Although it is advisable in all sheet-copper work to solder the seams on the back where they cannot be seen, it nevertheless often happens that some parts must be soldered on the front. The solder does not change color like the copper, and, consequently, when not properly treated, such seams tend to spoil the appearance of the work.

To give solder a copper color, it is necessary to deposit a copper plating on it. This is accomplished by first thoroughly scouring the seams, and then washing them with a solution of *sulphate of copper* and water. The solution should be strong. When applied with a brush to the solder, a film, or plating, of metallic copper is immediately formed over the solder, and by repeated applications a fairly substantial coating of copper is obtained.

WINDOW SILLS, LINTELS, AND CAPS

28. Window sills are made of sheet metal to represent cut-stone sills. They should be filled in behind with timber of the proper size. The metal sills are usually slipped over the wood backing and are fastened to the wall by nailing closely through the flange *a*, Fig. 16, which extends along the bottom and up the sides. The top flange *b* is made wider than that at *a*; it is nailed against the window frame, and is bedded in white or red lead to make it watertight. A better plan, however, is to bed the window frame over the metal sill with red or white lead, the metal being flanged and passing up

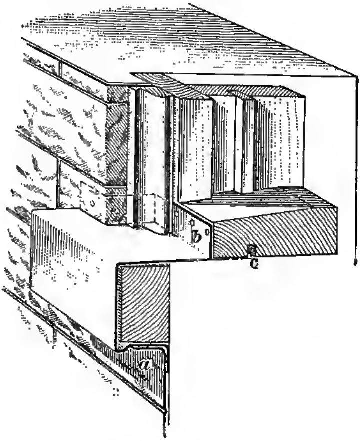


FIG. 16

into the groove *c*. Metal window sills are generally used on galvanized-iron fronts. Copper is seldom used for this work.

29. **Window lintels** are covered in a similar manner, the chief difference being that the top flange of the lintel is overlapped by the metal siding above it. The soffit of the lintel flanges down against the top of the window frame and is nailed to it. Particular care, however, should be taken to have a well-inclined wash on the lintel. Horizontal surfaces, particularly pocketed surfaces, are very objectionable and should always be avoided.

30. The covering of bay windows, architraves, pediments, etc. depends altogether on the design. An important point to be considered in the line of sheet-metal work for bay windows, pediments, etc., is the provision for lookouts and other projections to which the cornice and other moldings must be attached. Small moldings are usually placed on the flat sheathed surfaces, while lookouts are required for cornices and other large projections. It is advisable, in all the work, to provide solid backing for the sheet metal. When wooden lookouts are used, they should be so made that the metal work can be nailed across the grain of the wood, not with it. The expansion and contraction of the metal soon draws out and loosens all nails driven in the direction of the grain.

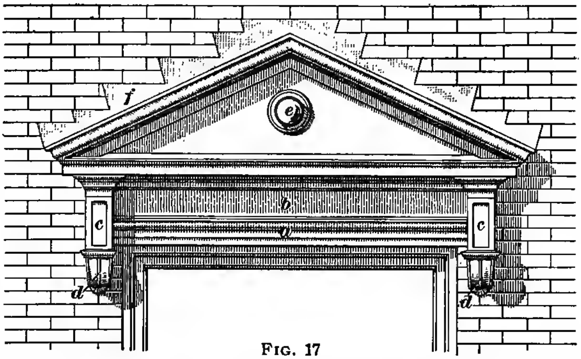


FIG. 17

31. Window caps, like all other ornamental parts of sheet-metal work, are made up from stock sizes and shapes of bent or stamped sheet metal. Fig. 17 shows a sheet-metal window composed of an architrave *a*, a frieze *b*, and two impost blocks *c*, *c* supported by brackets, or trusses, *d*, *d*. The impost blocks support the pediment *e*, and a counterflashing at *f* against the brick wall makes the top water-tight. If the cap is put on after the walls are built, it is customary to fasten it in place against wooden lookouts, as shown at *b*, Fig. 18. Furring strips *a*, *a* are nailed to soft-pine plugs previously driven into the wall, and the lookouts *b* are set about 1 foot apart along the line of the furring strips and nailed to them. Two special lookouts are to support the trusses. The sheet-metal cap is then set over these lookouts and is rigidly nailed to them. The metal is extended under the soffit of the lintels and flanged down against the hanging tile of the window frame, and is neatly finished with an angle molding bedded in white lead and well nailed in place. The wash *c* of the cornice is turned up against the wall and is counterflashed in the usual manner.

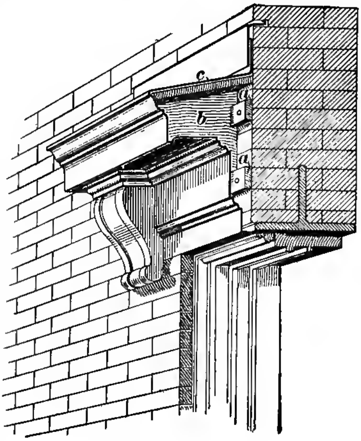
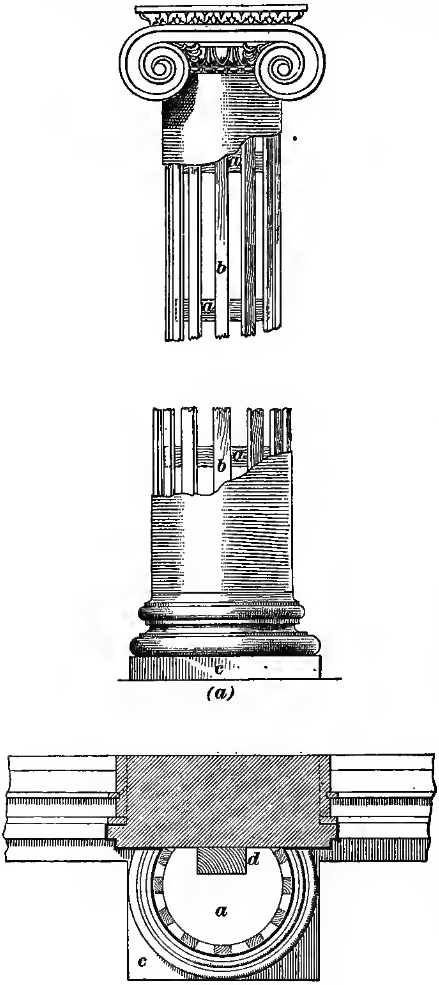


FIG. 18

If the wall has not been built, it is advisable to use iron lookouts and build them in the brickwork when the wall has been brought up to the proper height. The upper surface of all window caps, sills, and cornices should be carefully protected during the erection of the building. Every window cap, and indeed every other projecting molding or cornice, should be closed water-tight on top with a sloping deck, or wash, and should be sufficiently strong to sustain the weight of a man.

COLUMNS

32. There are many kinds of columns and pilasters, and different methods of constructing them. In a general way, however, Fig. 19 illustrates common practice. This figure shows in elevation at (*a*), and in section at (*b*), a three-quarter column, such as is used for the front of a building. The column is braced by wooden blocking, which is composed of 1½- or 2-inch horizontal blocks *a*, *a* that are spiked to an upright post *d* and spaced at intervals of not more than 2 feet. Vertical strips *b*, *b* are nailed to the face of the blocks, and are run from the square plinth *c* to the top of the capital. The sheet metal that forms the column is continued down to the plinth, and up to the block or other member over the capital, the seam on *c* being soldered water-tight. The back edges of the sheet are nailed to the face of the wall in the regular manner. The base is then put in place and



(*a*)

(*b*)

Fig. 19

soldered to the column, after which the capital should be soldered to the column. This is one of the best methods of bracing sheet-metal columns.

The same method is employed in fireproof construction, except that iron is used instead of wood. Pilasters are formed and covered in the same manner as columns. In all column and pilaster construction, the formation of pockets wherein water may accumulate should be avoided.

FIRE-DOORS AND FIRE-SHUTTERS

33. Wooden fire-doors may be covered with any kind of sheet metal that has a high temperature of fusion. Copper and zinc are not suitable for this work; galvanized iron and tin are therefore used, though tin seems to have the preference. The covering is generally put on as follows: The outer edges of the door are covered first with a strip of tin, which is returned over both faces to a distance of about 6 inches, the edges being nailed to the woodwork and turned over, as shown in Fig. 20. The flat part of the door is then covered with sheets 14 in. × 20 in., in a manner similar to that employed on flat roofing. This arrangement avoids seams around the edges of the door, and allows it to shut with a close contact. A heavy body metal should be employed for this work, because the efficiency of the covering in case of fire depends on the thickness of the metal, and not on the thickness or quality of the protecting coat. The seams should all be closely nailed, and then locked and

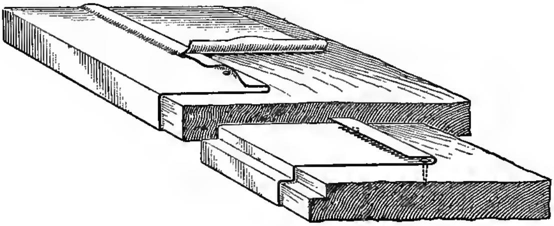


Fig. 20

thoroughly pounded down. A layer of asbestos cloth should be placed between the tin and the wood.

Corrugated-iron doors and **shutters** are also extensively used, but they do not form as efficient fire-stops as ordinary wooden doors or shutters that are properly covered with tin and asbestos. The corrugated iron must be thoroughly braced with an angle-iron or **T**-iron frame.

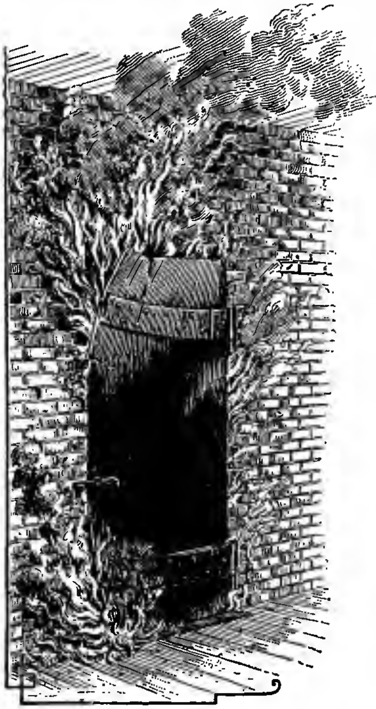


Fig. 21

The greatest objection to iron fire-doors and fire-shutters is that they warp very easily when attacked by flames. Plain iron warps so much that it is practically useless as a fire-stop. Fig. 21 furnishes a good illustration of this. The door shown is composed of one sheet of thick metal, and is provided with iron cross-pieces to which the hinges are riveted. The fire plays against the inside of the door and warps the sheet outwards, thus allowing an opening for the flames, as shown.

COPINGS

34. Wall Copings.—The tops of all brick walls must be made waterproof, otherwise rain will soak into the wall heads and ultimately ruin them. When cheap, light coping stones are used, it is necessary to lay a sheet of metal (preferably lead or copper) under them, as shown in Fig. 22. The sheet metal is simply laid on the brickwork and bent over about 1 or 2 inches at each edge. The stones are then bedded in place in the usual manner.

35. Coping Blocks.—When coping blocks are used to surmount cornices, the flashing or wash of the crown may be extended through to the back of the wall, where it may connect to the roof covering, or to a gutter lining, as the case may be. When it is necessary, however, to entirely cover the blocking course with the same kind of metal as the cornice, the metal work of the cornice may be extended up and continued over the blocking course, as shown in Fig. 23, the sheets being crimped and held in place by cleats in the seams *a*, *b*, and *c*. A wooden wall cap is placed on top of the brickwork to protect the top course and to take the cleat nails.

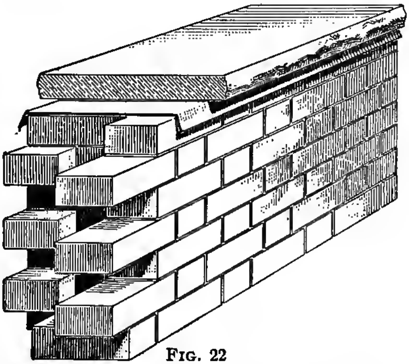


FIG. 22

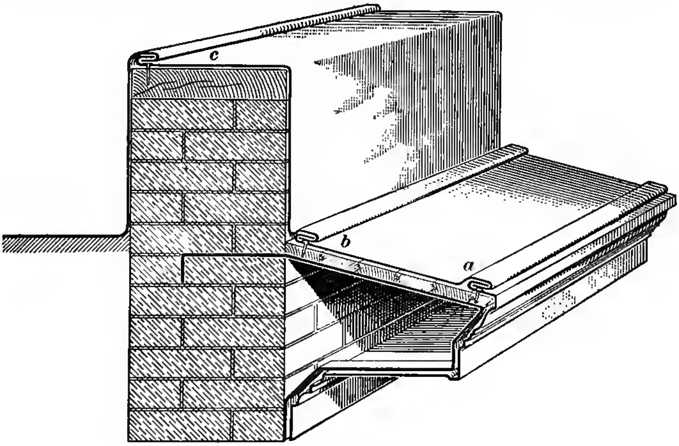


FIG. 23

36. Stone cornices may be flashed as shown in Fig. 24. The copper is bent over the face of the stone and doubled over with a beaded edge on the under side to form a drip.

This also prevents the flashing from rising in front. When the top surface is narrow—that is, less than 12 inches—it does not need to be fastened, but when it is wide, the copper should be held down with fastenings, as shown at *a* and *b*.

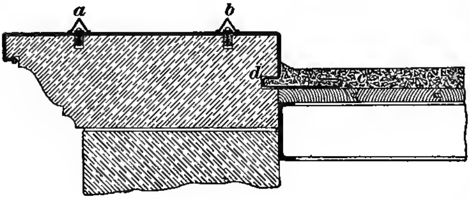


FIG. 24

The arrangement shown in Fig. 24 is used at the junction of a stone cornice and an asphalt roof laid on fireproof construction, the asphalt covering being shown at *c*. Sometimes the copper is bent down flat over the back of the stone, but the best method of attaching it is to groove the stone at the back and let the copper into it, as shown at *d*. This holds down the flashing at the back.

37. The common method of fastening the sheet to the stone is to drill $\frac{1}{2}$- or $\frac{5}{8}$-inch holes at intervals over the surface of the stone and fill these holes with lead. The holes should be cut wider at the bottom than at the top, so that the lead plugs cannot be pulled out. After the holes are drilled, an iron rod, whose diameter is less than that of the screws to be used, is greased and placed upright in each hole. Molten lead is then poured around the rod until the hole is full. The rod is then pulled out, and when the flashing is all laid and neatly set in place, it is screwed down to the lead plugs with brass screws.

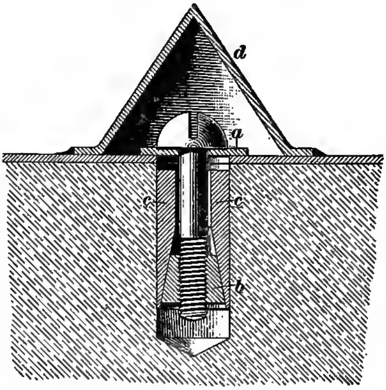


FIG. 25

Expansion bolts, shown in Fig. 25, are now generally used for fasteners. After the holes are drilled and the stone covered, the holes are "found" and the expansion bolts are inserted. A washer *a* is placed between the bolt head and the copper, and the bolt is screwed down tight. This draws up the tapered, or wedge-shaped, nut *b* and presses the sides *c*, *c* against the sides of the hole. A cone *d* is then soldered over the fastener, as shown, to make it water-tight. If the fasteners are not used, the copper is likely to rattle when the wind blows.

38. Chimney caps are made in different styles. The most simple, and perhaps most common, form is a plain sheet-metal cap that is slipped down over the brickwork about 6 inches, the sides of the cap being nailed into the joints of the brickwork. A superior chimney cap, however, is shown at *a*, Fig. 26. The brick chimney is built up to the course *b*, then the cap is bedded on, and finally the brickwork *c* is filled in from the top, so that its weight on the flange, which is turned over the course *b*, will prevent the cap from being blown off. The moldings of the cap, being of small projection, do not require any lookouts. The brickwork must, however, be built up tight to the top of the cap to prevent it from settling down and flattening the molding.

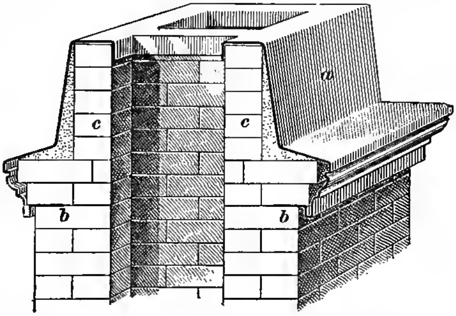


Fig. 26

BALUSTRADES

39. Balustrades, like cornices, etc., are constructed either with wooden or with fireproof supports, the kind to be employed depending on the construction of the building. Balustrades, pedestals, etc. on non-fireproof buildings are usually backed with, or secured to, woodwork, while those on fireproof buildings are nearly always supported by ironwork or brickwork.

Fig. 27 is a section through a balustrade that is commonly employed where the cornice deck pitches to the front and the roof pitches to the rear. The base rail *a* extends down to the deck, the metal being flanged over and soldered to the roofing.

When the deck over the cornice grades back toward the balustrade, and when the base rail extends down to the deck, it is necessary to solder in drain tubes to take away the water. This will prevent a pool of water from forming against the base of the balustrade. The trouble, however, with such tubes is that they are liable to become clogged with snow, etc. The best arrangement is to elevate the base rail 2 or 3 inches above the deck. Roof-cornice decks, in fact, should always pitch back to the roof to prevent rain from dripping over the cornice. When the base rail does not extend down to the deck, it is usually composed of solid timber and is entirely covered with sheet metal.

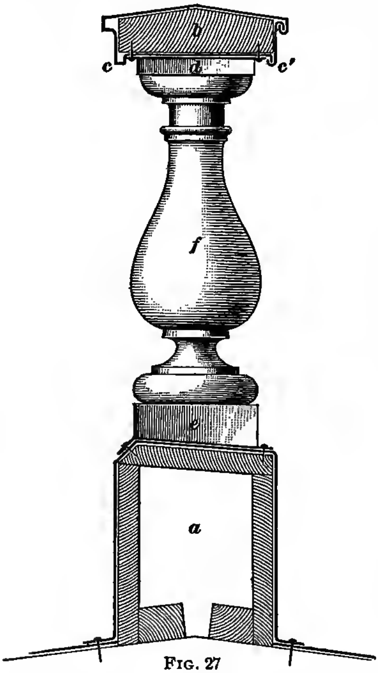


FIG. 27

To prevent the rail from sagging, wooden blocks covered with sheet metal are frequently inserted under the rail at distances varying from 6 to 8 feet apart. The coverings of these blocks are bent over at the top and nailed to the under side of the base rail, while at the bottom they are bent out and soldered as a flange to the deck.

The cap rail *b*, Fig. 27, is usually made of wood and is covered with two pieces of sheet metal with drips formed at *c*, *c'*, as shown. The seams are made at the rear.

40. The balusters *f*, Fig. 27, are spun, pressed, or cast. If they are spun or cast, there will be no vertical joints in their length. If they are pressed, they are put together in halves, which necessitates two vertical soldered seams. Pressed metal is generally used on ordinary work because it is much cheaper than spun or cast metal. The top member *d* and the bottom member *e* of the baluster are usually square. All the members are securely riveted and soldered together before the baluster is set in position. After the cap and base rails are in place and lined up properly, the balusters, which are hollow and flanged at top and bottom, are pushed into place. The flanges are securely nailed to the under side of *b* and to the top of *a*, as shown, the bottom flange of each baluster being soldered water-tight over the nail heads. The top flanges are not soldered, because the drips protect them.

It is generally understood that sheet-metal balusters are strong enough to support the top rail under ordinary conditions; but in cases where a load is likely to be placed on the cap rail, it is advisable to put a strut inside of each baluster, which will take the load off the metal and prevent the baluster from collapsing.

In fireproof construction, the general arrangement is the same, the principal difference being that iron backing is used instead of wood, and that the metal is bolted to the ironwork in a manner similar to that prescribed for cornices.

41. A **pedestal,** as ordinarily constructed, is composed of a framework made of 3″ × 4″ timber, which is spiked to the roof and sheathed, as shown in Fig. 28. The projections necessary for the moldings, etc. are blocked out. In the figure, the pedestal is provided with a panel face and a flat back. The sides may be paneled or plain. The dotted lines show the relative position of the balusters *a* and the cap and base rails with respect to the pedestals.

The sheet metal for the front and sides is made to fit the pedestal and is then put on in one piece. The back piece is then put in place and double-seamed to the sides, flanges *b*,*b′* being formed at the base and soldered to the deck. The top is then put on and double-seamed over a flange, as shown at *c*, *c*; the double seam is shown turned down and finished at *c*, while it is only half finished at *c'*. The molding, or projection at *d*, is returned on the pedestal and miters with the top rail. The base block, in a like manner, returns and miters with the base rail of the balustrade. If a finial or vase is to be set on the pedestal, the connection should be made with a flange at *e* and should be lock-seamed and soldered water-tight.

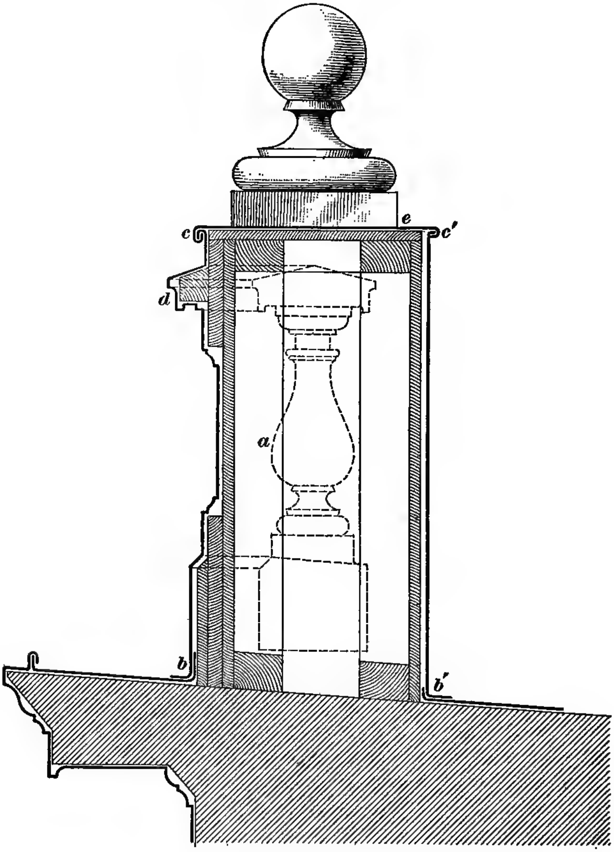


Fig. 28

Corner pedestals are paneled on two sides; this necessitates a vertical seam on the outside and inside corners of the pedestal.

In fireproof construction, the backing for the pedestals is usually composed of brickwork when they are located immediately over the wall head. The sheet-metal covering is then made up in one piece and is slipped down over the brickwork, being fastened to the deck with a flanged seam, as shown in Fig. 28. The top sheet, also, is fastened in a manner similar to that shown in Fig. 28.

When a tall finial that requires a support has to be set, it is advisable to run a rod or iron pipe up through the center of the pedestal and screw the top member of the finial to this support.

When a solid brick backing cannot be obtained, it is necessary to construct a framework of wrought iron, which is thoroughly braced diagonally and bolted to the roof. The metal covering is then placed around the frame, and bolted or riveted in position in the usual manner.

GUTTERS

42. The varieties of gutters that will be treated of in this Section are: *eaves gutters*, *roof gutters*, *parapet gutters*, and *belt-course gutters* of various materials and for various classes of buildings.

An eaves gutter of the simplest kind is shown in Fig. 29; it is known as a **half-round hanging**, or **trough, gutter**, and is commonly used on ordinary frame buildings. The standard widths are 3, 4, and 5 inches measured across the top of the inside. The bead is about $\frac{1}{2}$ inch in

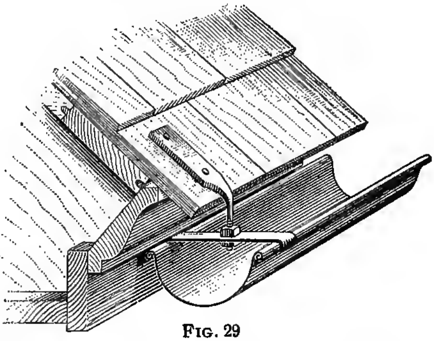


FIG. 29

diameter and is turned outwards. These gutters are suspended from the eaves with adjustable malleable-iron hangers set at about 3 feet centers. When they are attached to shingle roofs, the hangers may be simply nailed or screwed to the shingles as shown in Fig. 29. A neater method, however, is shown in Fig. 30, where the hangers are firmly nailed to the roof-boarding before the shingles or slates are laid. The pitch or grade of hanging gutters should not be less than 1 inch in 10 feet and the gutters should be hung low enough to allow the snow to slide over them.

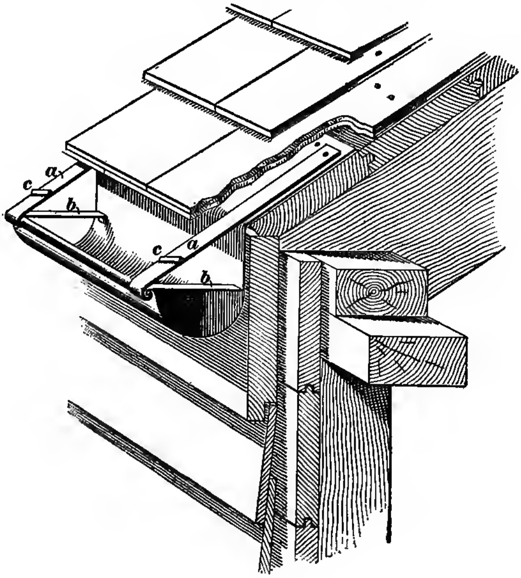


FIG. 30

Three-inch gutters are useful only for porches, bay windows, and other small roofs. The 4-inch size should be used on the main roof when the horizontal or projected area does not exceed 500 square feet. The 5-inch size is used chiefly on factories, warehouses, and at the rear of large city buildings, where the projected area does not exceed 1,500 square feet. Hanging gutters of this class should be used only when the eaves overhang the wall.

When a hanging gutter is attached close to the wall, the back of the gutter is extended up under the shingles or slates at least 6 inches, as shown in Fig. 30, the object being to prevent heavy winds from blowing rain drops against the siding. The gutter is held up in front by tension straps *a*, *a*. The lower ends of the straps are soldered to the bead, and the upper ends are nailed to the roof. Braces *b*, *b* are soldered inside, and above the water-line, to prevent the gutter from sagging or collapsing. Small clips *c*, *c* are soldered on the straps at an angle, to divert any current of water that may flow along the strap and thus escape over the edge of the gutter. This gutter should be graded about the same as that shown in Fig. 29.

43. Molded Eaves Gutters.—Molded, that is, ornamental, eaves gutters are often attached to buildings in a manner very similar to that shown in Fig. 30, but while the gutter in this figure is laid with a pitch, such molded gutters are laid perfectly horizontal. In this respect they are defective, because all gutters should pitch down to the outlet pipes. In good practice, it is advisable not to run a gutter with a horizontal bottom, not only because the gutter is liable to overflow during heavy rain storms, but because a pool of water will remain in the bed of the gutter after the rain has ceased. To prevent an overflow, it is necessary to make molded eaves gutters quite large; and to properly drain them, it is necessary in some cases to install a false bottom that will grade down to the point of outlet with a suitable pitch.

When the gutters are made of iron, they should always be graded in order to prevent deposits of mud, which hasten corrosion.

44. Fig. 31 shows a **copper molded eaves gutter** set on the top of a brick wall of a fireproof building, which is provided with a terra-cotta roof covered with slates. The bed of the gutter rests on a board *a*, which is inclined so as to give the proper pitch. The face of the gutter forms a continuous horizontal molding and is made from cold-rolled sheet copper. The front edge of the gutter lining is bent down over the face and is lock-seamed to the copper molding as shown.

The back of the gutter is extended up over the terra-cotta slabs *d* and under the slates *e*. A series of brass straps *c* are spaced off along the gutter and secured at distances of not more than 3 feet, being bolted to the plank *b* in front with brass lagscrews. The rear end of each strap is run up under the slates and bolted through the terra-cotta slabs with brass bolts of proper length, large brass washers or plates being used under the slabs to prevent the nuts from sinking into them. Each strap is twisted one-half of a turn, as shown, to prevent roof water from working over the face of the gutter. The sheet copper is doubled and pinched at *i* to form a drip. In cold climates, it is advisable to slope the back of the gutter, the space behind being thoroughly filled in solid. This will prevent the gutter from bursting with the formation of ice, if the conductor pipe should choke and the gutter fill with water.

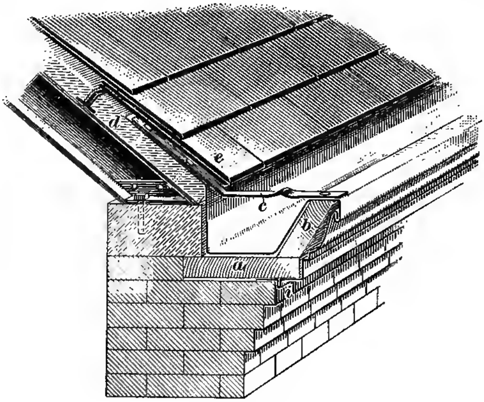


Fig. 31

45. Roof Gutters.—Fig. 32 shows a simple form of roof gutter. It consists of a board nailed to the roof and braced by brackets *a*, *a*. The board is laid on an incline to form the proper grade, and the lining, which is usually bright tin or terne plate, is continued up under the shingles, and nailed down. The front edge is doubled over a strip of metal

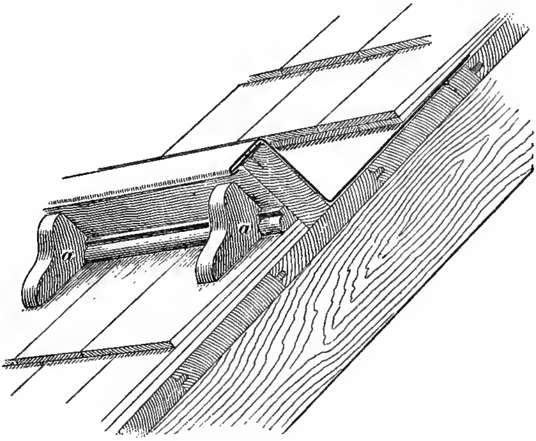


Fig. 32

that has previously been closely nailed to the woodwork. An edge fastened in this manner is called a *blind-nailed edge.*

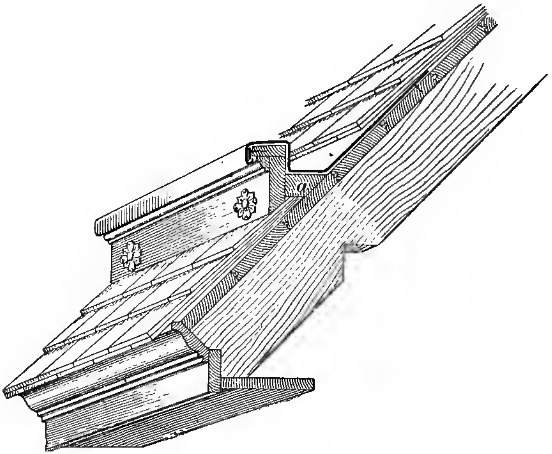


Fig. 33

The necessary incline of this gutter spoils its appearance; to form a roof gutter that will appear parallel with the roof, it is necessary to build it in a manner similar to that shown in Fig. 33. A tapering gutter strip *a*, usually 2 inches thick, is laid to run the whole length of the gutter, and grades the bottom in a proper manner. These gutters really form snow boards, and during winter often become so clogged with snow that the water from melting snow cannot run off the roof freely, but is forced to pass through between the shingles or slates and thus cause a temporary leakage. For this reason, roof gutters are not to be recommended for roofs with a low pitch.

46. Cornice Gutters.—The cornice of a building is very often constructed so it will serve as a gutter also. A **wooden cornice gutter,** sometimes called a *box gutter*, as shown in Fig. 34, is employed in the construction of the better class of framed buildings. The carpenter completes the cornice and forms the bottom of the gutter with the proper grade. The tinsmith then lines the gutter before the shingles or slates are laid. The lining, like those in Figs. 32 and 33, is nailed to the roof and over the front edge of the gutter with a blind edge, as shown.

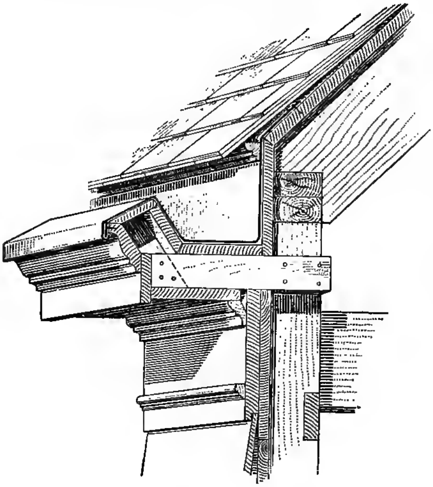


Fig. 34

Sheet-metal cornice gutters are constructed on the same general principle.

47. Terra-Cotta Cornice Gutters.—A terra-cotta cornice gutter for a fireproof building is shown in Fig. 35. The terra-cotta slab *a* of the cornice is backed by brickwork *b*, on which rest the I beams *c* of the roof trusses. The usual angle- or T-iron purlins support the porous terra-cotta slabs. The mason fills in the gutter bed *e* with cement concrete and grades it to the proper pitch. The sheet metal, which is generally 16- or 18-ounce soft- or hot-rolled copper, is then bent up and laid into the gutter, the front edge being bent down into a groove *f*, which is molded in the terra cotta, and the back edge is run up the roof and is overlapped by the slates or tiles in the usual manner. The connection between the copper and the terra cotta is made water-tight by filling the groove full of molten lead, which, when cold, is solidly calked with a hammer and calking tool. If this method of attachment is not desired, the cornice may be molded with a dovetailed projection, so that the metal may be sprung over it as shown in Fig. 36. This will hold down the copper, but it is not so solid as the chalked joint shown in Fig. 35.

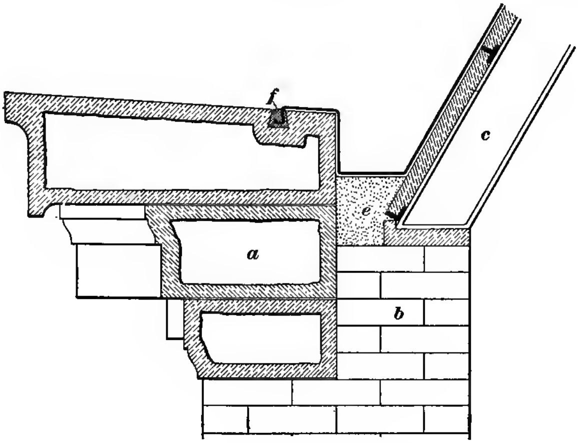


FIG. 35

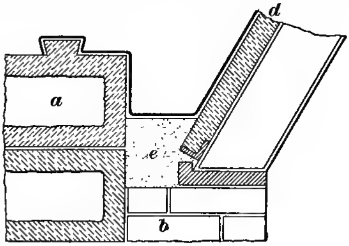


FIG. 36

48. **Parapet Gutters.**—A parapet gutter for a building of modern fireproof construction is shown in Fig. 37. The only notable difference between this and the box gutters

already described is the fact that the gutter is located behind a wall that is higher than the point to which the gutter is extended under the slates. It will be readily seen that there is great danger of the building being flooded if the leader opening should become covered with leaves or dirt, so that rain water cannot escape down the conductor pipe *a* as fast as it flows into the gutter. To avoid this difficulty, an *overflow tube b*, having a sectional area at least equal to, but preferably greater than, that of the conductor pipe, should extend through the wall as shown.

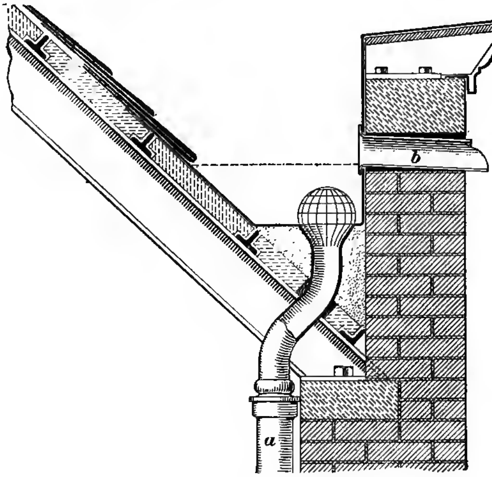


FIG. 37

The bottom of the overflow opening should not be less than 5 inches above the lowest point of the gutter bed, but not high enough to cause the water to overflow any upstands or flashings that the gutter may be provided with. In the figure, the sheet copper composing the gutter and the rear covering of the parapet wall is all in one piece; consequently, the main consideration in locating the overflow tube here is to prevent the water from backing up under the slates and leaking over the top edge of the flashing. The sill of this gutter, like that shown in Fig. 35, is filled in with cement and graded down to the conductor opening.

When the parapet wall is extended higher than about 18 inches or 2 feet above the gutter, it is customary to flash the back into the wall, as shown at *a*, Fig. 38. A joint in the brickwork is raked out to a distance of about 1½ inches, and the copper is bent over and let in as shown. Soft cast-lead bats *b*, *b* are then driven solidly into the reglet, about 6 or 8 inches apart, after which the reglet is filled with elastic cement. The objection to this arrangement, however, is that the expansion and contraction of the gutter is liable to loosen the bats, and the reglet joint may leak.

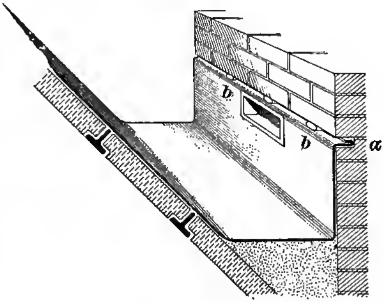


FIG. 38

49. A better arrangement is shown in Fig. 39, in which the gutter is not nailed down or secured at any point except at the conductor opening. The upstand *a* back of the parapet is held down by a number of *cleats b*, of which the tops are doubled over the top of the upstand and the lower ends are bedded in the cement sill. A counterflashing *c* of lead or copper is batted into the reglet and overlaps the upstand at least 3 inches. The top of the overflow tube *d* should be on a line with the top of the upstand or a little below it. To avoid nailing down the gutter at the back,

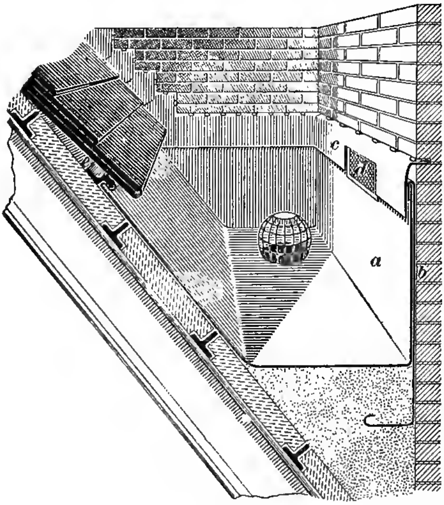


FIG. 39

also to prevent it from rising or shifting, an iron or brass *tilting fillet e* is bolted to the fireproof roofing. The sheet copper is bent under and doubled over this fillet, as shown. The tilting fillet is also advantageous to the slater, because it enables him to start the bottom course of slates with the proper cant.

50. Wooden Tilting Fillets.—Wooden tilting fillets are used when the roof is covered with boards. The fillet is shaped as shown at *a*, Fig. 40, and extends the full length of the gutter. A number of strong cleats *b* are nailed to the roof and bent over the fillet. The gutter is then laid and the cleats are doubled back over the edge, as shown. This is considered first-class practice. The method of laying slates or shingles flat on sheet-metal gutters, valleys, flanks, or other flashings should never be followed. Water will work up between them by capillary attraction.

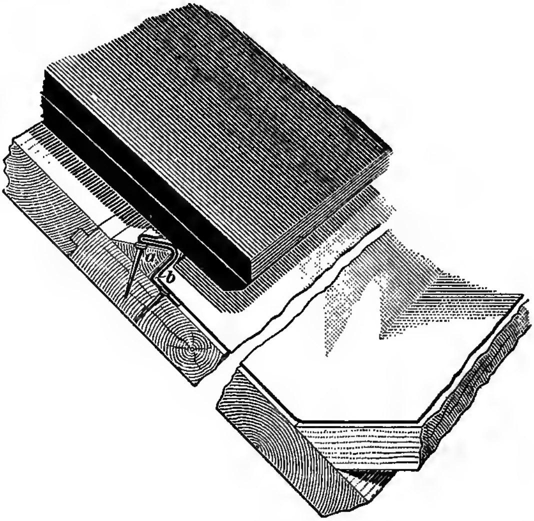


FIG. 40

51. Corbel-Table Gutter.—A corbel-table gutter is shown in Fig. 41. It is supposed to form a belt all around the building, being located about 4 or 5 feet below the eaves.

Such gutters, being so far below the eaves, do not carry much water at any time; they simply serve to carry off the drip. The greater part of the water shed by the roof during heavy showers, shoots over the gutter, this action being most pronounced when the roof covering is of a corrugated character.

A corbel table *a*, which rests on corbels *b*, *b*, forms a support for the gutter. The lookouts *c* are made of cast iron and are set at about 2 feet centers all along the table, their prongs being let into the mortar joint at the back about 2 inches. The crown molding and its wash are made of copper, the lower edge being lapped about 4 inches over the top of *a*. The top edge is fastened with cleats to an iron bar. Another iron strap, or bar, at *e* runs the full length of the gutter, and the copper is fastened to it with brass bolts. When the molding is in position and properly lined up, the mason fills in the gutter with cement to form a curved bottom with the proper grade. Strong cold-rolled copper cleats *f*

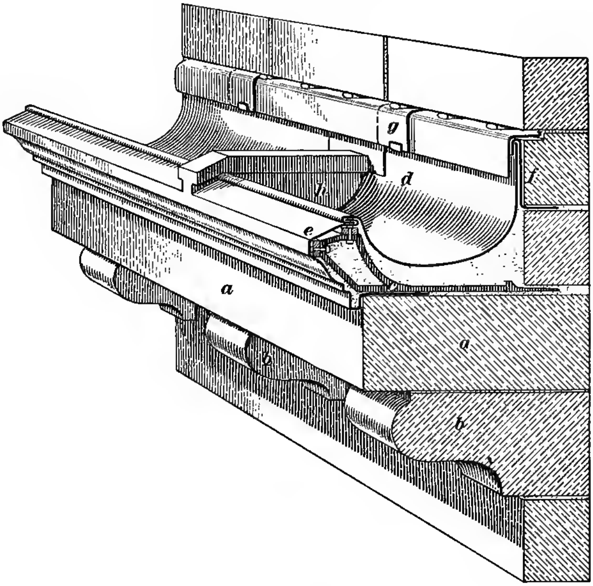


FIG. 41

are secured to the wall to hold down the back of the gutter *d*; the front edge is double-seamed and soldered as shown. The back is counterflashed in the ordinary manner. If the counterflashing is of lead, the top joints *g* should be locked into one another at the lower edge, as shown, to prevent the wind from raising the corners.

52. When such gutters are long, some provision should be made for expansion and contraction, otherwise they will soon tear apart and leak. In Fig. 41, this is accomplished by introducing a *saddleback joint* at *h*, a cross-section of which is shown in Fig. 42. A plank *i*, Fig. 42, 2 inches thick, that has been previously soaked in oil or asphalt, is set on edge and bedded in the concrete. If the gutters are laid during hot weather the upstands *j*, *j* should be fitted to almost touch the plank, so that during winter, when the gutter becomes intensely cold and contracts, the upstands will be drawn away from the board and take the position shown by the dotted lines. This forms an expansion joint of the best type. The cap, being short, is nailed to the wood and the nail heads are covered with a copper disk, which is soldered water-tight around the edge.

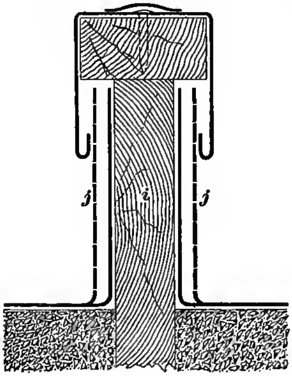


FIG. 42

CONDUCTORS

53. Conductors, or **leaders,** as they are often called, are the pipes that conduct or lead away water from the gutters. They may be classed as *inside* or *outside leaders.* Inside leaders are not treated in this Section.

54. Outside Leaders.—Outside leaders are fitted up against the outside of a building. They are made in many shapes and of different metals. Fig. 43 shows the **round-pipe leader** as usually erected. These leaders are most always made of tin by the tinsmith, who also makes the elbows *a*, *a*, *a*, which, usually, are altogether too sharp. Tin straps *b*, *b* are soldered to the leader at intervals of about 6 or 8 feet and are nailed to the walls, as shown. Round leaders are not suitable for outside service in cold climates because they persistently freeze and burst.

Fig. 43 illustrates an ever-recurring spectacle in cold weather, when snow lies on the roof and the temperature of the air is below the freezing point. The sun shines on the roof, but not on the leader; thus, the snow on the roof melts and the water trickles down the leader, and, by the time it nearly reaches the bottom it becomes frozen to the sides of the leader. This ice slowly thickens until the leader is entirely choked at that point which, in Fig. 43, is the lowest elbow.

The remainder of the melted snow then gathers in the leader and fills it. This water now solidifies and bursts the leader as shown. The pipe has burst because it could not stretch enough to accommodate the increase in volume of the water as it was changed into ice.

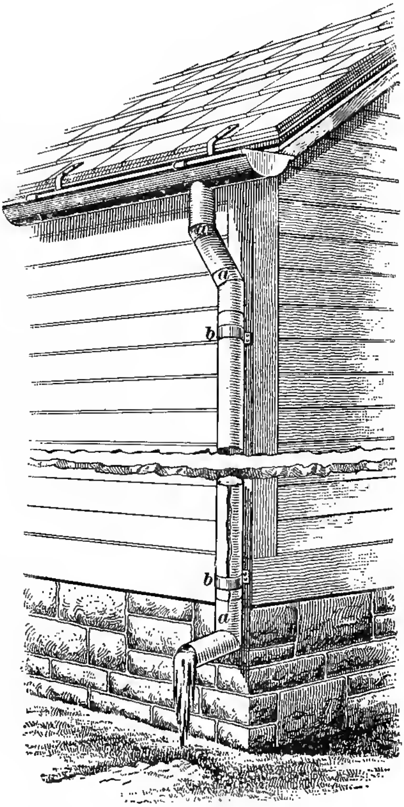


Fig. 43

55. Expanding Pipes.—Expanding pipes should be used to overcome the trouble from frost. A common form, shown in Fig. 44, is simply a corrugated round pipe. The corrugations allow the pipe to increase enough in diameter to compensate for the formation of ice inside, without bursting the pipe. If the pipe is frozen repeatedly, it will ultimately burst, because it takes a permanent set every time it is thus expanded. These pipes are usually made of galvanized iron or cold-rolled copper, in 8- or 10-foot lengths.

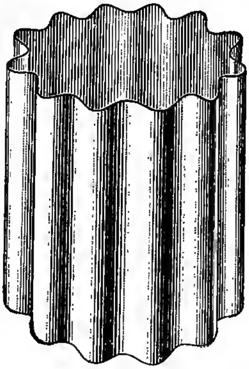
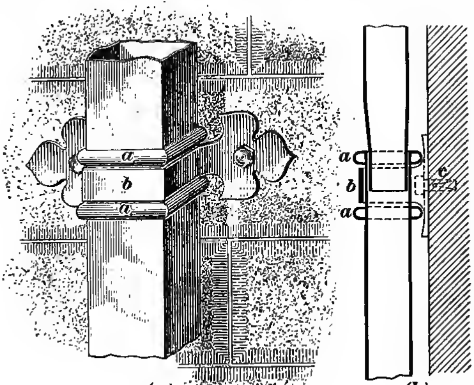


FIG. 44

56. Square or Rectangular Leaders.—These leaders are made of crimped or corrugated sheet metal, and are often used to obtain a more ornamental effect than is produced by round leaders. They should be supported by ornamental bands in a manner very similar to the plain straps shown in Fig. 43, the straps being made so that the leaders will hug the wall. If the walls are built of masonry or brickwork, it will be necessary to drill holes at the back of the bands, and then drive soft-pine plugs into these holes, cutting them flush with the face of the wall for the purpose of receiving the spikes; for good work, expansion bolts should be used.



(a) (b)

FIG. 45

In climates where there is no danger of outside leaders being frozen, the best method of attaching rectangular leaders in a neat and strong manner to brick, stone, or terra-cotta walls is shown in elevation in Fig. 45 (*a*) and in section in Fig. 45 (*b*). Two copper beads *a*, *a* are soldered around the top edge of each leader and a cast-copper band *b*, provided with ornamental lugs, clasps the top of the leader against the building. The lugs are fastened to the walls with expansion bolts, as shown by dotted lines at *c*. The leaders are connected together by slip joints, as shown in the section. Each band thus supports a section of the leader, which should not exceed 8 feet in length. This arrangement allows each section to expand and contract freely; if all the joints are soldered together, the leader forms into one long rigid line, which soon becomes loosened by expansion and contraction. These leaders should be made with the crimps running across them, not lengthwise, so as to secure a very neat, flat, and stiff surface.

Beaded tops and cast bands are not adapted for outside leaders in cold climates, because the beads and the bands are not pliable enough to resist the action of frost. The best attachment for such climates is composed of either a brass or a copper eye, which is riveted and soldered securely to the back of the top end of each section of the leader. These eyes are bolted to bronze hooks that are secured to the wall. An ornamental stamped sheet-copper band is then slipped on between the heads to conceal the real rigid attachment. The lugs of the band should be attached to the wall by expansion bolts. This arrangement gives a pliable joint. The corrugations in this leader, however, should run lengthwise, and all the joints should be slip joints. Iron supports should never be used in or against a stone wall, because they rust and stain the masonry.

57. Offsets in leaders should always be avoided. It is common practice to offset the leaders at stone, brick, and terra-cotta moldings, but in good practice they should be fitted up straight and plumb, the necessary holes being cut through special blocks formed in the molded courses for the passage of the leaders. It is customary to discharge sheet-metal leaders into a cast-iron pipe, which is continued up about 4 or 5 feet above the surface of the ground, the object being to prevent the leader from being flattened or otherwise injured. Rectangular leaders should, for the sake of appearance, connect at the bottom with a rectangular cast-iron pipe, and not with a round pipe.

58. Size of Leaders.—The proper size of leaders, of course, will vary with the climate, the amount of rainfall, and the manner in which the gutter catches the water; but a good safe rule for every-day practice is to allow 1 square inch of sectional area of conductor pipe for every 75 square feet of flat-roof area. No leaders, however, should be less than 2 inches in diameter, and even this size should be used only for small roofs, such as those over bay windows, small porches, etc.

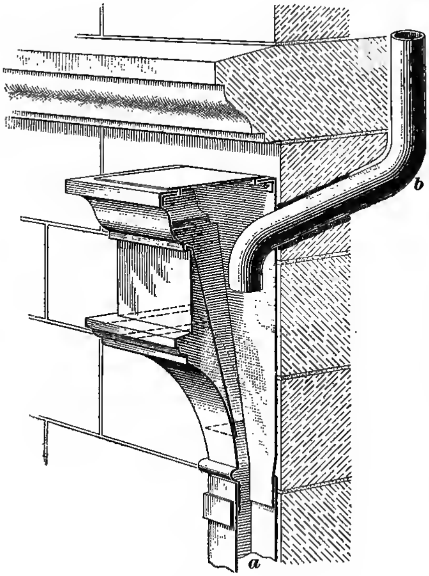


FIG. 46

The *underground pipe* (often drain tile), into which the leaders discharge, should not be less than 4 inches, inside diameter, and they need not be more than 8 inches in diameter for any work where the roof area is less than 1 acre. In measuring the watershed of pitched roofs, calculate the projected or horizontal area—that is, the area on the plan.

59. Rain-water heads, sometimes called *conductor heads*, are often employed on the top of a leader, and treated as an architectural feature by forming a graceful outline to the receptacle for the gutter discharge. Two or more leaders may deliver into one head, as the conditions may require.

Fig. 46 shows a conductor head in section. It is set on top of a rectangular, corrugated, sheet-metal leader *a*, which should be securely fastened to the wall with a band on top. The lower end of the head slips into the conductor, and the top is fastened to the stone wall with expansion bolts or other fasteners. A brass angle should be fitted inside the rim. The roof gutter empties into the head through a large lead or copper pipe *b*, which runs up a chase in the back of the wall, thus concealing it from outward view. The top of the head should be covered to prevent birds from building their nests in it, or in the pipe *b*. The proper position for a rain-water head should be carefully shown on the elevation, as mechanics are prone to set them at the handiest place, without reference to the architectural treatment of the façade. All rain-water heads should be lined inside with a tapering box, to extend below all moldings and prevent possible leakage, and also to prevent noise during heavy rains.

60. Strainers.—Every leader opening in a gutter should be provided with a strainer to hold back leaves, twigs, etc., and to prevent birds from building nests in the leaders. The best strainers are those constructed of a ball or hemispherical form, like those shown in Figs. 37 and 39.

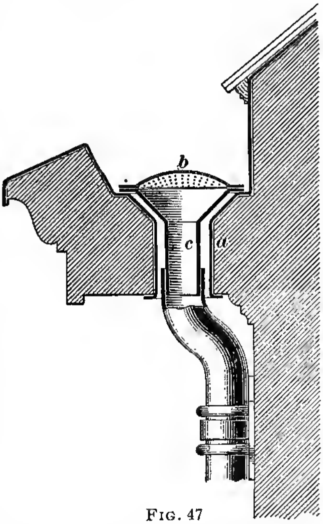


FIG. 47

For ordinary purposes, where the roof water flows to waste, wire ball strainers, put together something like bird cages, are generally used. But in cases where the roof water is gathered into cisterns or tanks and stored for domestic use, the strainers must be very close in order to prevent pieces of leaves, etc. from being washed down into the cisterns. Such vegetable matter soon decays and pollutes the water. The strainer *b*, Fig. 47, is specially made for this service. It has a very large straining area, which is closely perforated with holes not larger than $\frac{1}{8}$ inch.

61. Gutter connections to leader pipes are very important details and should be carefully considered. The offsets necessary for cornice and overhanging gutters should have a good grade from gutter to leader, and should be composed of easy bends—not sharp elbows. Owing to the fact that leaders are liable to freeze, it is advisable to provide outside gutter connections with a tube, as shown at *a*, Fig. 47. This tube is soldered to the gutter lining on top, and may be flanged over the face of the soffit of the cornice at the bottom, as shown, thus forming a water-tight channel through which the leader pipe *c* passes. If the leader should freeze and burst between the gutter and the soffit of the cornice, the tube *a* will prevent the water from leaking into the cornice, which, if made of wood, will soon cause the decay of the material.

When copper leaders connect with tin-lined gutters, or vice versa, it is advisable to make the gutter tube *c*, Fig. 47, of the same material as that used for the gutter lining. If different kinds of materials are employed for this purpose, a galvanic action may occur between the two metals, which will hasten corrosion. The connection of the gutter tube to the leader is made with a slip joint.

62. Leader Cut-Off.—When the leaders discharge into cisterns or tanks, it is advisable in all cases to provide them with cut-offs, so that the water may be discharged to waste or into the cisterns, as desired. Every roof is foul, to a certain extent, with decaying vegetation, bird lime, etc., and all this matter is washed off during the first few minutes of a rain storm. If a cut-off is not used, the dirt, of course, goes into the cistern. It is customary to leave the cut-off free from rain to flow to waste until the roof is supposed to be washed clean, then it is turned so that the remainder of the water will flow into the cistern.

There are many kinds of cut-offs on the market. Some are made to be operated by hand, while others are intended to operate automatically, when a certain volume of rain water has passed through to waste. The latter are preferable, if reliable, because the hand cut-off is likely to be neglected.

DOMES AND LANTERNS

63. In many parts of Europe, it is customary to cover domes, lanterns, cupolas, etc. with sheet lead; but, in the United States, owing to the great variations in temperature that are encountered, it is necessary to use a metal that is better adapted to withstand the unavoidable expansion and contraction.

Sheet copper or galvanized iron are the best metals for use in countries where excessive changes in temperature occur. The latter, however, is not durable enough for covering domes, lanterns, or cupolas, and, consequently, sheet copper is generally employed.

There are different methods of covering domes, but the following four may be considered preferable: namely, *plain* or *smooth*, *ribbed*, *paneled*, and *metallic shingle* or *slate coverings*.

64. Smooth covering is usually put on domes in a manner similar to that employed in flat-roof covering, with flat locked seams, each sheet being well tied down with strong cold-rolled copper cleats. If the dome is large, the ordinary flat sheets about 20 in. × 28 in. are generally used, the curvature of the dome being so slight that the soft copper will easily adapt itself to the shape. When the dome is small, however, each sheet must be blocked out to the proper curve, so that the covering, when finished, will have a neat smooth appearance and be free from buckles. The greatest objection to locked-seam covering is the liability to leakage, chiefly through the seams, on the nearly horizontal parts of the dome. The solder will spoil the appearance of the dome if the copper work is allowed to retain its natural color.

65. Ribbed Surface Covering.—To avoid leakage on domes by the effects of expansion and contraction, and to prevent any solder from discoloring the copper work, some form of ribbed covering is employed. This requires the use of a standing or a roll seam, as the character of the building may demand.

The space between the standing seams or rolls should not be more than 2 feet wide, and the sheets should not be more than 4 feet long. They must be securely supported from the top edge, preferably with heavy cold-rolled copper cleats.

It is advisable in all first-class sheet-metal roofing to avoid driving nails through the sheets at any point. The sheets are thus permitted to freely expand and contract without tearing the metal.

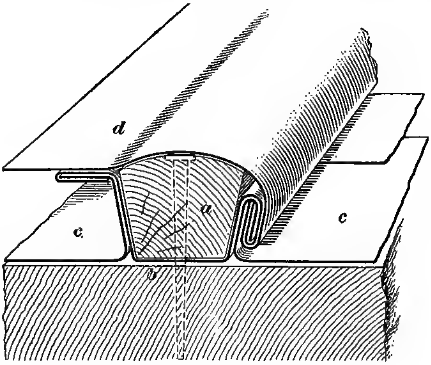


Fig. 48

An excellent roll seam is shown in Fig. 48. The batten, or roll strip, *a* is nailed down over a long cleat strip *b*. The sheets *c*, *c* are then sprung in between the rolls and the cleat strip is doubled over the upstand. The roll cap *d* is then put on over the roll, and locked into the cleated upstand as shown. The roofing sheets, cleat strips, and roll caps are thus all locked together and made water-tight, and yet are free to expand and contract individually. The batten nails combined with the outward curvature, which the sheets *c* must necessarily have, will prevent a gale from rattling or loosening the sheets.

66. Horizontal Seams.—The best form of horizontal seam that can be made on domes is shown in Fig. 49. A strong cold-rolled copper cleat strip *a* is nailed to the roof with flathead brass or copper nails; and the top edge of the under sheet, the bottom edge of the upper sheet, and the cleat strip are all locked together as shown. With this arrangement, each sheet can expand and contract lengthwise without affecting the stability of the support. If the sheets are simply lapped at this seam, the wind will get underneath and raise them in the middle, thus opening the seams and making them visible from the street.

When it is required to set the rolls more than 2 feet apart, it becomes necessary to support the sheets between the rolls. This is accomplished in different ways. The sheets may be laid so that the horizontal locked seams will be about 18 or 20 inches apart, the rolls being perhaps 4 or 5 feet apart. When very large sheets must be used, however, *secret tacks a*, Fig. 50, are riveted and soldered to the back of the sheet *b* at intervals, which will allow about 2 or 3 square feet to be supported by each tack. As the sheets are being put on, the tacks are pushed into long, narrow holes in the woodwork, and then pulled through and nailed to the inside of the dome as shown.

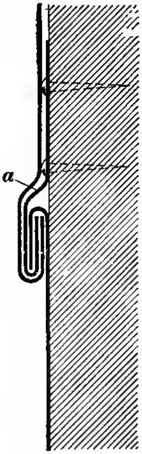


FIG. 49

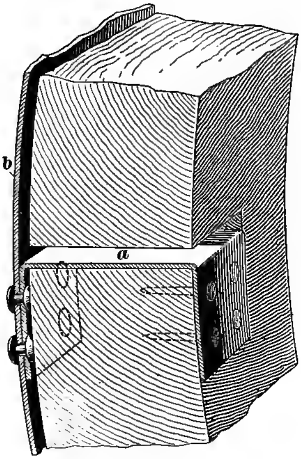


FIG. 50

67. Location of Rolls.—In locating the position of the rolls, it is necessary to consider the general construction of the edifice, both above and below the dome. The ribs or

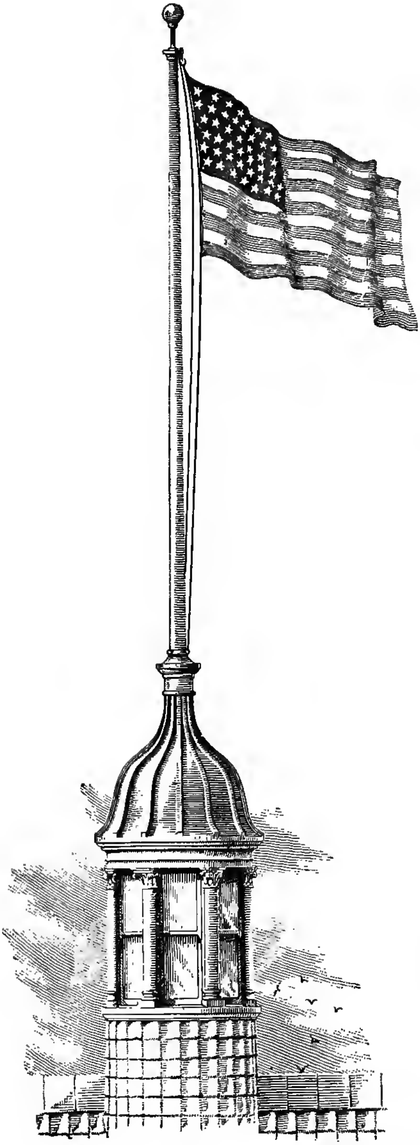


FIG. 51

rolls should not be put up to suit the standard stock sizes of copper sheets, but they should be located to harmonize with the leading architectural features of the composition.

For example, consider the dome of the cupola, or lantern, shown in Fig. 51. The ribs here divide the dome surface into equal sections, two sections being immediately over each window opening. Every second rib is directly in line with the center line of a column. When the sheets are drawn closely together at the top, as shown, the ribs are usually tapered, being wider at the bottom than at the top; but when there is considerable space between the top ends of the ribs, they are usually made the same width throughout their length.

68. The Paneled Dome.—A paneled dome is shown in elevation in Fig. 52. The lantern under the dome is octagonal in form, with a window *a* in each side. The dome, however, is round in plan with a panel *b* located directly over each window. The top of the dome is surmounted by a statue, the base of which is shown at *c*. A vertical section through the dome and a few details are shown in Fig. 53. The elevation, Fig. 52, shows ribs *d*, *d* running from the cornice of the lantern up to the base of the statue, but these may be omitted.

At *e* in the detail, Fig. 53 (*a*), is shown a method of securing the panels in place without ribs, when there is no panel molding. The panels are simply double-seamed with cleat strips to the stile strip *e*, as shown. But where ribs are desired on the stiles, or when moldings must be run around the panels, the connections may be made as shown at *f* in the same detail. If the panels have a larger surface than 3 or 4 square feet, secret tacks may be employed to advantage, as shown by dotted lines. A detail of the top molding of each panel is shown in view (*b*), and a detail of the bottom and the wash over the corona of the lantern is shown in (*c*). These seams are all made in the shop, being locked and thoroughly soldered at the back, with the exception of *i*, which is made in place and is thoroughly cleated and soldered. The statue base *c*, Fig. 52, is slipped down over a sheet-copper collar, and is fastened to the top of the dome with

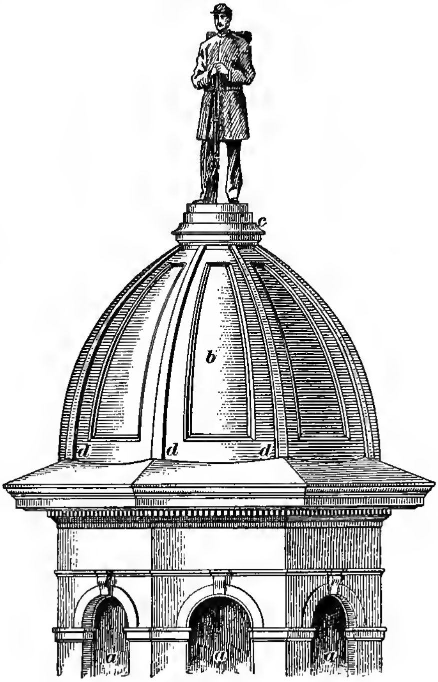


FIG. 52

four bronze bolts, which are threaded close under their heads to make a permanent water-tight connection. Fish-plates and nuts are employed underneath in the ordinary manner.

69. Flagpole Flashings.—Flagpole flashings, and those around all other forms of movable finials, require much attention to detail, as they must be made water-tight, and remain water-tight under peculiar conditions. Every flagpole sways more or less, according to its strength, the pressure of the wind, etc., and, therefore, a rigid flashing at its base cannot be durable. The liability of the pole to "settle down" is another matter to be considered. On this account, it is advisable to use *slip joints*, or telescope flashings, which

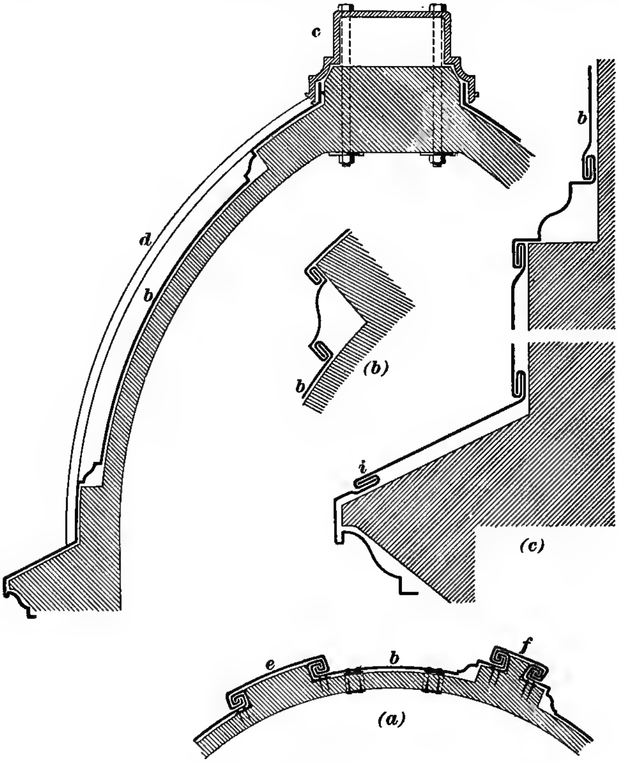


Fig. 53.

are provided with enough clear space, or "play," to allow the pole to move or sway in any direction without touching or affecting the sheet-metal covering of the dome. A good arrangement is shown in Fig. 54, which is, in fact, a detail of the intersection between the flagpole and the cupola shown in Fig. 51. The rolls of the dome finish inside of the bead *a*. The copper work finishes around the top member *b*. A bonnet *c*, made of sheet lead weighing 8 pounds per square foot, encircles the pole and covers the member *b*. The top of the bonnet is "dressed" close into a small groove in the pole, which is cut just deep enough to allow the lead to finish flush, a bed of red and white lead being used to make the connection water-tight. The bonnet is nailed to the pole with a ring of 1-inch, pointed, flathead copper nails, which may be concealed with a bead *d* if desired. The lower edge of the bonnet overhangs the block *b* and forms an open lap joint around the top of the copper. The top of the block *b* is well greased, and the bonnet is free to slide as the pole sways.

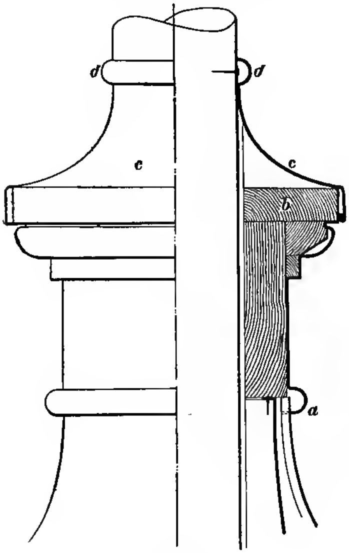


FIG. 54

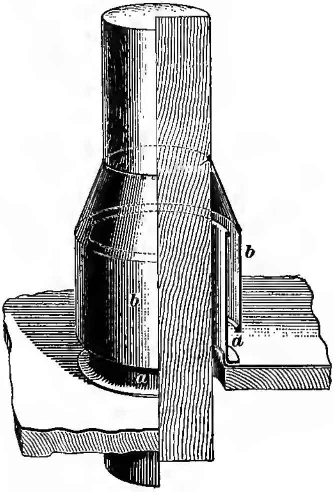


FIG. 55

When the pole intersects a flat roof, a plain slip-joint connection, like that shown in Fig. 55, may be used. A cylinder, or upstand, *a* is soldered to the roof. A sleeve *b* overhangs the upstand and is nailed to the pole as shown, a space being provided on each side of the upstand to allow the pole and its flashings to move in any direction.

70. Flagpole Cap.—The top of a pole should always be protected either by a sheet-metal flashing or by a cap. A flagpole cap, with regulation ball, is shown in Fig. 56, which is a detail of the cap shown in Fig. 51. A brass casting *a* fits snugly over the top of the pole and is fastened to it with brass screws. An eyebolt at the left holds the flag pulley. A piece of brass tube *b* joins the cap to a brass spud *c*, which is soldered to a seamless copper ball.

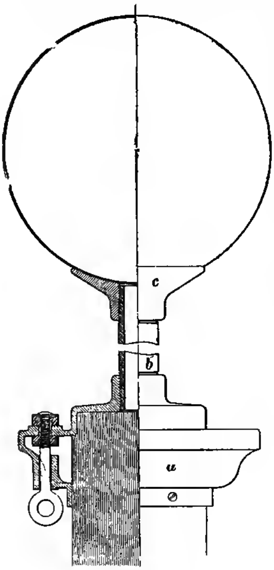


FIG. 56

This style of cap not only protects the pole from the weather, but provides a suitable pulley connection, and gives an artistic finish to the apex of the flagpole.

CRESTINGS

71. Sheet-metal crestings are of varied design and construction; they can, in fact, be made in any design that is adapted to stone or terra cotta. The most important features to consider in crestings are the method of support and the connection to slate or shingle roofs. Ordinary crestings are so constructed that the nail heads in the top course of slates are left exposed to the weather. This is a mistake, as rain will certainly follow the nails and cause slight leakage, which may not be visible, but which, nevertheless, hastens the decay of the timber and rusts the nails.

72. Attachment.—Fig. 57 shows a method of attaching sheet-metal cresting on ridges and hips in such a manner that all nail heads are concealed. Channel strips *a*, *a* of strong sheet metal are bent to the shape shown and nailed on the roof close to the ridge pole. The top course of slates is then pushed in the channel and fastened with the nails *b*, *b*, as shown. The cresting *c* is then sprung over the channel strips and the lower edges are closed into them, thus locking the cresting and the channel strips together. The edges at *d* are locked together to prevent wind from lifting or rattling the cresting. When the ornamentation projects more than 9 inches, it is advisable to nail suitable lookouts on the top of the ridge pole.

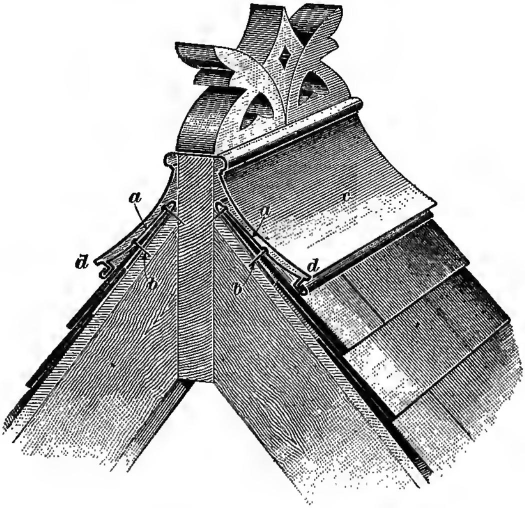


FIG. 57

The joints in crestings should be made in a manner similar to that already prescribed for cornices.

FINIALS

73. Finials less than about 7 feet in height are usually built in the shop to conform with the drawings of the architect, and are taken to the building and erected in one piece. Larger finials, however, are usually set up in two or more pieces, according to their height, weight, and form. All the joints should be double-seamed and soldered inside, in the same manner as cornice joints.

Finials having round members are built up from either *spun* or *pressed metal.* Spun metal is preferable. Other forms are built together in different ways, according to the shape of the members.

All finials should be securely supported to prevent them from sagging, and braced to prevent them from leaning out of plumb. The system of supporting and bracing required will depend on the shape and the size of the finial. In some finials, a straight iron pipe alone will form a satisfactory support, while others must be provided with lookouts, like cornices, and often with braced framework. Fig. 58 shows a simple and efficient method of supporting a long narrow

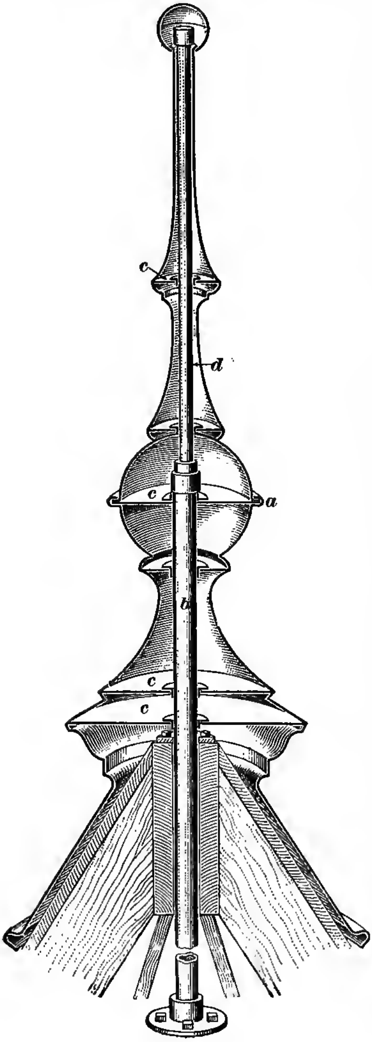


Fig. 58

finial on the peak of a conical roof. This finial is taken to the building in two pieces, and is joined together in position, with a lock seam *a* around the ball. A 2- or 3-inch galvanized-iron pipe *b* is securely supported and braced to the framework of the roof. Horizontal partitions *c*, *c* are soldered to the inner surface of the finial and snugly fit the

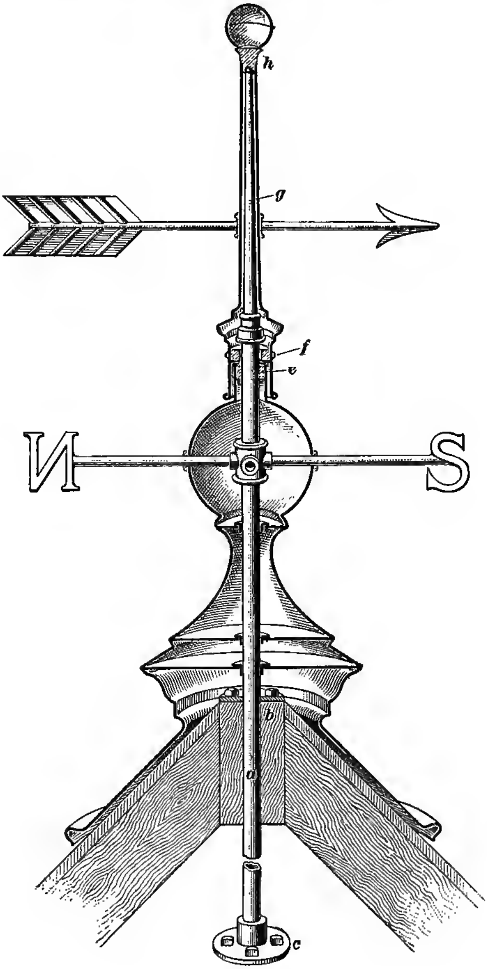


FIG. 59

iron pipe; these form braces and keep the finial straight. A few vertical gussets are soldered inside the ball to strengthen it vertically. A threaded pipe coupling is soldered inside the top ball so that this ball may be securely attached to the top of the pipe *d*.

74. Weather vanes are a class of finials provided with a movable part that rotates on a vertical axis by the force of the wind. They are employed to show the direction in which the wind blows and consequently are provided with the letters N, S, E, W, located respectively north, south, east, and west of the axis of the finial. These letters are secured to the stationary part of the finial. An arrow, or some other form of indicator or pointer, is also employed in the construction; this is attached to the movable part of the finial. Fig. 59 is a vertical section through a simple weather vane. It is similar to the finial shown in Fig. 58, except that the top part is made to rotate. An iron pipe *a*, which rests on a solid footing, passes vertically through the apex of the roof. A collar at *b* and a cross-beam at *c* rigidly secure the pipe and keep it plumb. A special fitting, called a *double-cross*, receives the arms that support the four letters already mentioned. These arms also reinforce the ball. The top of the stationary sheet-metal work is riveted to a brass ring *e*. The bottom of the movable part of the vane is bolted to a brass ring *f*. These rings keep the copper in proper shape at the slip joint. The lower end of a tapered steel bar *g* is screwed into the reducing socket on top of the pipe. The top end of the rod is tapered off to a sharp pivot point, and works in a brass socket *h*. This rod must be free and clear from the copper shell around it, so that the arrow may swing around to face the wind with the least possible resistance. The movable section must be carefully balanced; it should be so sensitive that a man can move it with his breath. The ring *f* is located under the reducing socket, and prevents the movable section from being thrown off in a storm.

75. Interior Sheet-Metal Work.—Sheet metal is seldom used in the interior of buildings except for covering walls, ceilings, etc., and even then it is only used for a cheap grade of work, so as to obtain the most elaborate effects at a very low cost. The principal items for consideration are the methods of fastening the sheets to the building and the selection of a design from manufacturers' stock.

It is customary for the sheet-metal worker to nail furring strips on the ceiling and walls at such distances apart as will conform with the design stamped on the sheets, but in no case should they be more than 1 foot apart. In selecting the furring strips for ceilings, particular care should be taken to allow for sufficient depth for any electric-wire conduits or gas pipes. The sheets are laid on the walls to overlap one another, and the nails are driven through the ornamentation in such a manner as to apparently form a part of the decoration. The lap seams should all be laid so that the light from the windows will shine against the edges of the sheets and thus avoid shadows, which would indicate the location of the seams.

All sheet-metal wainscoting, baseboards, dados, and chair rails, and, in fact, all ornamental sheet-metal work that is likely to be damaged by rough treatment, should be "pugged" behind with Portland cement.

All heavy moldings and cornices should be backed by lookout brackets cut to the proper profile. All wood backing should be covered with asbestos sheets when it is desired to form a fireproof enclosure. Plain black-steel sheets should be dipped in iron oxide and linseed oil before they are put up. In all damp places, it is advisable to use bright tin or zinc; the latter is preferable.

MATERIALS USED IN SHEET-METAL WORK

76. Black iron or **steel** is used only for the very cheapest roofing and siding, also for interior decoration or fireproofing. No. 26 gauge is generally used. In all cases, the sheets must be protected against corrosion by metallic paint or other suitable coatings.

77. Galvanized iron is used for sheet-metal siding, cornices, plain brackets, plain trusses, plain modillions, corrugated roofing, etc. No. 26 gauge metal is generally used throughout. No. 24 metal, however, is preferable for all large moldings.

78. Zinc is seldom used for covering buildings in the United States. But owing to the fact that it can be pressed into ornaments better than iron, it is employed for ornamental trusses, brackets, modillions, rosettes, festoons, etc., in galvanized sheet-metal fronts, and for balusters in balustrades. All zinc and galvanized sheet-metal work may be soldered on the face. All galvanized ironwork should be painted with a zinc body paint.

79. Cold-rolled copper is always used for copper cornices, moldings, columns, and all plain surface work that is to be formed in copper. The weight of the copper should not be less than 14 ounces, and it need not be more than 20 ounces on the very best class of buildings; 16-ounce copper is commonly used on good work, while 18-ounce is reserved for heavy moldings. All cold-rolled copper work should be fastened in place with brass or copper nails, screws, or bolts, as the conditions may require. All soldering should be concealed. When it is desired to paint copper work, the metal should be tinned all over the face to prevent the copper from coming in contact with the paint.

80. Soft-rolled copper is often called *hot-rolled copper* and is used for lining gutters, valleys, etc., and for pressed or hammered ornaments. The weight generally specified is 16 ounces, and 18 or 20 ounces on such work as may be subject to much wear and tear, either by expansion and contraction or by rough usage.

Soft copper, tinned on both sides, is best adapted for gutters and all other work that depends on solder for tightness and strength. Copper cleats should always be cold-rolled.

81. Soldering.—Sheet-metal seams should be soldered very slowly, because it takes time to properly sweat a seam, and very hot, well-tinned, soldering irons should be used. Any mechanic discovered "rushing" a seam or hastily skinning it over with solder should be immediately discharged and all his work should be resweated by a careful man, as the durability of sheet-metal work depends chiefly on the soldered seams.

Resin should be used as a flux for all tinned copper, and chloride of zinc for all plain copper, galvanized iron, and zinc. Raw muriatic acid or sal ammoniac should not be used as a flux.

82. Tarred roofing felt should be laid under all sheet-metal roof work and gutters, to protect the under side of the metal from moisture and deleterious vapors, also to form a soft protecting cushion for the metal.

83. Woodwork.—All woodwork under sheet-metal roofing should be smooth and evenly laid and properly graded by the carpenter. Nail heads, knot holes, and sharp corners are detrimental to sheet-metal work.